AIR-CONDITIONING

Air-Conditioning

Being a short treatise on the Humidification,
Ventilation, Cooling, and the hygiene
of Textile Factories—especially
with relation to those in
the U. S. A.

By

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PREFACE.

In the following pages I have endeavoured to set down a collection of various information and observations that I have had the good fortune to make during the last few years, in various textile countries and districts, which I trust may be of some service to practical mill men and those interested in the textile industries, and in bringing before them the importance of further investigation into that very ill-understood and intangible subject called "air-conditioning."

I have been requested by friends interested in the textile world to set down the information and observations that I have been able to gather during the few years of study that I have devoted to this subject, and I have therefore complied with their requests in the hope that this may prove to be an incentive to further and more exhaustive research of what is one of the most important trade questions in America.

Very little reading matter has been published on this question, and apart from the circulars and catalogues distributed by parties directly interested in the sale of their own particular apparatus, very little is known in America of the methods employed abroad.

"Air-conditioning" is a question of vital importance to the American textile trade and is, through unfortunate circumstances, one of the least understood. It is readily acknowledged that previous to the adoption of artificial methods, one of the main reasons that America was never able to successfully compete with European countries in the production of the finer qualities of yarns and fabrics, was largely owing to the fact that the atmospheric conditions prevalent on this side of the Atlantic were not as favourable to manufacture as were those abroad. Even at the present day, owing to the abnormal differences and changes in the atmospheric conditions, the greatest difficulty is found in maintaining the mills in a suitable condition for successful manufacture at all seasons of the year.

To me there is no question that there is a means whereby the maintenance of the required conditions can be obtained, but the matter has to be looked at from a practical standpoint and not as a theoretical problem, so whilst it might be possible to obtain the requisite conditions by giving "carte blanche" to some competent engineer, the questions of first cost, maintenance and complication of apparatus, etc., are of such importance to the successful working of a dividend-producing corporation, that a large expenditure of money is prohibitive and means must be found for a practical solution of the problem.

I am of the opinion that the successful solution of the problem has all but been arrived at and that it is now possible to equip a mill at a reasonable cost with apparatus that will meet, within certain bounds, with all the requirements of the trade, and in the following pages I have done my best to describe the questions of "air-conditioning," hygiene, and the different processes and apparati in use, as well as giving my humble opinion as to the most satisfactory methods of solving the problem.

I am aware that there are many points of interest connected with this subject which I have not touched upon, as well as many points which will no doubt at a later date be investigated by those with more leisure at their disposal, but I trust that my efforts may help in enabling my readers to make some practical use of my experiences and observations, and act as an incentive to further research.

I subscribe myself

G. B. Wilson.

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PART I.

PART I.

"Air-Conditioning."

During the years which I have devoted to the study of the question of "air-conditioning," connected with its application and relation to the textile industries, I have found very little information in printed form on a trade question of the highest importance, other than that contained in periodical papers read before bodies of textile manufacturers, and that contained in the catalogues and pamphlets issued by makers of "air-conditioning" apparatus.

I have long felt the importance of a proper examination of this very neglected question by technologists as well as by practical men, with a view to determining the best methods of overcoming the deficiencies in climatic conditions of certain countries and districts.

Manufacturers are too apt to neglect the scientific side of their business, and I trust that my efforts may serve a useful purpose in drawing their attention to this fact. These pages are meant not only for the student, but also for the experienced, practical man, and I hope that what I have attempted may prove to be an impetus to those who are interested in this question to make further investigations.

In the following pages I have attempted not only to describe the scientific and practical sides of the question, but also to give a history of the means by which artificial conditions are and have been obtained. I am fully conscious that I have by no means exhausted the subject, or have laid before my readers more than an outline of the question; I nevertheless feel that the information which I have been able to gather bit by bit, by practical experience and much reading, may be more than a matter of theoretical interest.

When the importance of the question is borne in mind, that one of the primary considerations to the success of the textile processes of manufacture depends on the suitableness of atmospheric conditions, it will be appreciated that the question has received none too much attention.

The science of the art of "air-conditioning" has been too much neglected in this country, and the trade has been too content in taking what means were put before them, without enquiring whether the conditions they sought might not be obtained in some better way. There is a large scope for the application of scientific principles to this question, and I am convinced that the more the minute details of the laws of nature are studied the more successful will be the results in the production of ideal manufacturing conditions, and I trust that when I have finished these pages I will have laid sufficient evidence to convince my readers of this fact.

All those who are engaged in the textile industries are aware how frequently conditions make their appearance for which no reasonable explanation can be given, and which are oftentimes the cause of serious monetary loss.

The range of this subject is so great that it is not possible to deal with all the detailed points of possible interest which may arise in connection with the influences of every locality, and I have had to lay down certain broad lines for myself, seeing that I have not yet had the opportunity to deal with many of the considerations which such a detailed extension would necessitate, and the further investigation of these points must therefore be left to those who have had the opportunities I have not had, and who can devote more time and leisure to the subject.

Influence of Suitable Atmospheric Conditions.

The importance of suitable climatic conditions to the manufacturing processes relating to textiles, into which the factors of temperature and humidity enter, were in the earlier and pre-scientific days fully recognised by the old-time spinners and manufacturers of England, and ignorant as they were of the laws and principles governing hygrometry and generally of the science and mechanics of air and water, their experience determined that some districts and localities were more favourable than others for successful manufacture. This experience which in their own proper interests led these pioneers and originators of this great industry to the well-sheltered vales of Lancashire, Yorkshire and Cheshire, where those conditions most favourable for their purposes were to be found.

Difference Between Present-Day Conditions and Those of Earlier Days.

In the earlier days, conditions governing the selection of mill sites were possible, which to-day are not, and the enormous expansion of trade, the dearness of land, and many other causes, have combined to make it impossible for the would-be manufacturer to procure a building site purely from consideration of its suitability, and in the generality of cases he is under the necessity of taking what he can get and relying on science to supply those conditions which are denied to him by circumstances.

Complication of the Problem by Present-Day Methods of Manufacture.

Not only has he these difficulties to contend with, but he has his problem further complicated by the up-to-date and improved methods of manufacture.

Static Electricity.

From the opener and scutcher to the spinning department in a cotton mill, and their equivalents in the other textiles, free electricity is given off and interferes with the process of manufacture in each department, resulting in inferiority in the product. These complications have been further increased by these improved methods of manufacture. The tremendously high speed at which modern machinery is driven to-day to obtain the full benefits of the new processes of manufactures, causes a great deal of friction and generates large quantities of what may be summarised as static or atmospheric electricity, and in the modern fireproof mills it is a common sight to see on a dry day the fibres standing out from the ironwork of the machines, pillars, etc., radially in the direction of the currents—infallible proof of the dearth of suitable conditions. This electricity has not only the effect of drying the air, but also of materially affecting the yarn in process of manufacture, the action being to draw out and separate the fibres, causing what is known as "oozy" yarn, and the combination of these two effects, of unsuitable locality and improved processes, causes innumerable breakages or "ends," much waste, "fly," fine impalpable dust, loss of time and the general spoiling of the quality and strength of the yarn.

The Nature of Textile Fabrics.

The cause of the above-described difficulty, in both natural and artificial conditions, is easily explained.

Textile fabrics are all of an hygroscopic nature and are highly sensitive to heat and moisture. Wool, silk and flax, though differing in detail of construction from cotton, present the same qualities, and I will therefore limit myself to the description of the cotton fibre for the purpose of explaining the sensitiveness of textiles in general to the variations in atmospheric conditions.

Structure of the Cotton Fibre.

In dealing with the structure of the cotton fibre it is not necessary for the purpose of this book to enter into the botanical relations of the cotton plant, and it will suffice to describe the fibre with a view to subsequently explaining the effects of temperature, humidity and electricity during its manipulation and conditioning in the factory.

Cotton is composed of an infinity of very close filaments, stuck or held together by waxy or gummy substances. These glutinous substances are contained in the woolly denticulated fibrous envelope surrounding the true cotton fibre, and though these substances are contained in a very small percentage in cotton when compared to those in other fibres, they play a very important part, which to go into the matter purely from a scientific standpoint would require much more space than I am at liberty to give to the subject.

Very hard when cold, these glutinous substances become softer and softer at every degree rise in temperature up to on an average of 180° F., at or about which point they melt.

Dr. Edward Schunck, F.R.S., speaking of cotton wax, states that the wax fuses at 186.8° F., and solidifies at 179.6° F. in American cotton, whereas the wax derived from Indian cotton (dhollerah) has the same melting point, but does not solidify until the temperature has reached 177.8° F. It is further stated that American cotton contains .48% of wax. This also explains why vaporising, when employed to fix the torsion of woven fabrics, has such a disastrous effect on cotton, even when exhaust steam is used, seeing that the operation is carried on at a temperature of 212° F.. this being far above the fusion point of the wax.

Influence of the Atmospheric Conditions on the Fibre.

As this wax forms a species of size, the fibres which are hard at a low temperature become more supple when the temperature is increased, enabling the processes of manufacture to be carried on with ease and success.

This is why a certain heat is necessary to spin cotton properly and under the best conditions, the softening or suppleness of the fibres being sufficient to enable the fibres to slide easily one over the other in the processes of "drawing" and "spinning."

When under adverse, dry or hot conditions, these fibres are very susceptible to the influence of static electricity, resulting in the fibres radiating from the centre of the yarn and making what is known as "oozy" yarn. It is therefore necessary to produce atmospheric conditions of the right degrees of heat and humidity to "kill" this electricity and to sufficiently melt the fibrous envelope, so that the moisture in the air can permeate, under osmotic action, into the inner cells, until it finally reaches the inner tube wherein is contained the true fibre.

The Relations of Cotton-Seed Oil to the "Setting" of Yarn.

The necessity for a relatively high temperature for spinning, especially in the case of fine counts, we have seen, is due to the presence of the wax or cotton-seed oil in the fibrous envelope. Upon the presence of this oil the "setting" of the yarn is dependent, and if the yarn has been spun in adverse conditions the strength is not only affected, but also the curl produced by the twist is difficult to overcome. This "setting" of the yarn is also to some extent governed by the subsidence of the static electricity to which it is subjected during manipulation.

The Three Points for Consideration.

The question therefore resolves itself into producing artificial conditions, where natural ones are unfavourable, which will enable the processes of textile manufacture to be carried on under the most favourable conditions, both to the materials and to the operatives.

The problem presents three distinct points for consideration, and these should be solved collectively in order to obtain the most perfect conditions.

They are as follows:

(1) In all seasons to be able to maintain in all parts of a building an elevated degree of humidity appropriate to the fabrication, and the ability to vary this humidity when necessary.

(2) To renew the air in a room in such a manner as to conform to the hygienic requirements, and appropriate to the style of work.

(3) To maintain the temperature within certain limits; to heat in winter as economically as possible, and to cool in summer.

Importance of Ventilation.

Before going into the first and third points mentioned above, I am of the opinion that the second point requires more than a little consideration, and although more attention has been paid to power ventilation in the United States than in any other country, textile mills seem to have paid little or no attention to its advantages, even in the face of the fact that process after process has been invented and put on the market abroad, which combine ventilation with humidification.

Suitable Textile Conditions and Their Relation to Health.

At first one is tempted to consider humidity in the air as hurtful, and it is certain that colds and all ailments which are classed under the name of colds are invariably contracted during excessively wet periods, fogs, etc.

Cutaneous evaporation and evaporation in the lung cells are necessary for the good working of the human system. In air saturated to excess the evaporation diminishes, and the resulting effect is pernicious to the health as well as disagreeable.

Sir Benjamin Dobson, who was an authority on this question, made observations which led him to the conclusion that the rate of mortality in English industrial centres where intense humidity is practiced is less than in other parts. It is an established fact in mills, that whereas atmosphere saturated to excess is harmful to the health, properly applied humidified air, such as is required for textile work, on the contrary, is quite the opposite. Such an atmosphere will always be healthier than dry, heated air containing dust and "fly" and gaseous impurities. It is well known that the impalpable dusts, etc., disengaged freely in the working of textiles, have a most disastrous effect on the respiratory organs.

The Effect of Humidity and Ventilation on "Fly."

Humidity in the air has the effect of diminishing in a large measure the presence of this "fly" and dust, and this purifies the air of rooms to such an extent that if combined with some efficient scheme of ventilation, it will reduce the evil as well as the carbonic dioxide and other gaseous impurities to a minimum. These results are, of course, to a very large extent, governed by the amount of air introduced in the building and the manner in which it is distributed.

Conditions in Old Mills.

In some old mills abroad, where the rooms are low and where electric light is not installed, gas being used, the hygienic conditions are very unfavourable, as apart from the floating dust and "fly," gaseous impurities, such as carbonic dioxide, etc., are given off by the gas lights, and the rooms towards the evening become extremely "close" and disagreeable, and a great number of cases of illness can be attributed to this reason. Operatives who are constantly working in a mill get used to an average temperature of 80° to 90° F. and complain if this temperature is reduced, and this must be borne in mind by the owner in ventilating his mills. In installing ventilation, the aim must therefore be to give sufficient air to produce good hygienic conditions and at the same time not reduce the temperature to too low a degree; if, however, the operatives can be made to see the advantages of cooler rooms, it is in my opinion to the advantage of the proprietor to do so.

Discomfort of CO_2.

To explain the discomforts caused by gaseous impurities in the air: Carbonic dioxide, or as it is more commonly known, carbonic acid gas (CO_2), exists in the atmosphere on an average proportion of three to four volumes per ten thousand (3 to 4 to 10,000) and is entirely negative in its properties, *i.e.,* it has no power to maintain animal life. When air is taken in by the lungs, a proportion of the oxygen is used up in making up for deficiencies created by the working of the human system in the purification of the blood, and the carbon given off, which rises to the lungs, chemically combines with another proportion of oxygen to form carbonic acid gas. Now, if this gas is contained in even the smallest proportion above the normal quantity in the atmosphere, it has a tendency to assert its negative qualities, and if contained in large proportions in the air, makes human beings feel uncomfortable and uneasy and detracts from their energy and health. It will therefore be understood that if a certain number of human beings are shut up in a room for hours without ventilation, a great quantity of CO_2 will accumulate, and as the room is practically sealed, the hygienic conditions will become very unfavourable, as will at once be noticed by anyone entering the room from the fresh air outside. Seeing that the specific gravity of CO_2 is greater than that of the air, it has a tendency to drop down and means must be found to keep the room in good hygienic conditions, to either force the air out or extract it.

It is said that an average human being breathes 18 times per minute, and at each indrawing of the breath takes in 25 cubic inches of air. This gives 15.6 cubic feet per hour, and the air exhaled from the lungs contains 5% of CO^2.

Assuming we have a room of 100,000 cubic feet of cubical contents in which 10 workpeople are at work, on starting work there will be 40 cubic feet of CO_2 present in the air (taking the normal proportion of 4 to 10,-000); at the end of an hour the workers will have increased this amount by 5% of 15.6 cubic feet $=$ .78 cubic feet $\times$ 10 $=$ 7.8 cubic feet of CO_2 present in the room to 47.8 volumes—raising the normal proportions by .78 volumes of CO_2 per 10,000 volumes of air per our. Taking this as an hypothetical case, if the room 'ere sealed it will be seen that at the end of a day's 'ork of 10 hours, the atmosphere of the room instead of ontaining 40 cubic feet of CO_2 would contain 118 cubic eet, making a proportion of 11.8 volumes of CO_2 per 0,000 of atmosphere, which would be most unhealthy.

COTTON CLOTH FACTORIES ACT, 1889.

Maximum Limits of Humidity of the Atmosphere at Given Temperature.

Dry Bulb Thermometers		Wet Bulb Thermometers		HUMIDITY	
A	B	C	D	Relative	Actual
60		58		88	5.1
	61		59	88	5.2
62		60		88	5.4
	63		61	88	5.6
64		62		88	5.8
	65		63	88	6.0
66		64		88	6.2
	67		65	88	6.4
68		66		88	6.6
	69		67	88	6.9
70		68		88	7.1
	71		68½	85.5	7.1
72		69		84	7.1
	73		70	84	7.4
74		70½		81.5	7.4
	75		71½	81.5	7.65
76		72		79	7.7
	77		73	79	8.0
78		73½		77	8.0
	79		74½	77.5	8.25
80		75½		77.5	8.55
	81		76	76	8.6
82		76½		74	8.65
	83		77½	74	8.85
84		78		72	8.9
	85		79	72	9.2
86		80		72	9.5
	87		80½	71	9.55
88		81½		71	9.9
	89		82½	71	10.25
90		83		69	10.3
	91		83½	68	10.35
92		84½		68	10.7
	93		85½	68	11.0
94		86		66	11.1
	95		87	66	11.5
96		88		66	11.8
	97		88½	65.5	11.9
98		89		64	12.0
	99		90	64	12.3
100		91		64	12.7

NOTE.—In columns A, B, C and D, the Dry Bulb and Wet Bulb Thermomer readings are given in degrees Fahrenheit. The Relative Humidity is ven in percentages (saturation = 100), and the Actual Humidity in grains moisture per cubic foot of air.

Cotton Cloth Factories Act.

In Great Britain Acts of Parliament have been passed regulating the hygiene of factories, and a standard of purity has been fixed by law that the CO^2 must not be present in the atmosphere above 9 volumes per 10,000 in mills where artificial humidity is practiced. This Act is known as the Cotton Cloth Factories Act, 1889, and is especially applicable to factories where artificial humidity is practiced.

The table on page 29 shows the percentage of humidity allowed by this Act.

Practically one can conclude from this Act that each operative should be supplied with approximately 15,000 cubic feet of air per hour, in which case the 10 operatives in our room of 100,000 cubic feet would require 150,000 cubic feet per hour, and a ventilation plant giving a volume of air one and a half times the cubical contents of the room would be necessary to conform to the Act.

Description of the Hygrometric Condition.

Leaving the question of ventilation for the moment, a description of the hygrometric conditions may be of some interest.

Air always contains a certain proportion of water vapour, but in extremely variable proportions. The absorbent capacity of air for water varies with the temperature, and the two factors of humidity and temperature are directly interdependent. For example, at 60°F air can only absorb 5.8 grains of aqueous vapour per cubic foot of air, whereas at 86°F it can absorb 13.2 grains per cubic foot, and so on to a greater degree in proportion to every degree rise in temperature. It follows, then, that when saturated air is cooled there is a separation of water in the form of fog or condensation. If saturated air is cooled from 86°F to 60°F there is 13.2—5.8=7.4 grains of water per cubic foot separated, and yet the air at 60°F still remains saturated.

It has been stated that the air can absorb 13.2 grains of water per cubic foot at 86°F; if, therefore, there is only 6.6 grains of water per cubic foot contained in the air at this temperature, the relative humidity will only be 50%. Now, dealing with air at 60°F, it will contain 50% of relative humidity when it contains $\frac{5.8}{2}$ grains =2.9 grains of water per cubic foot, and yet in both cases we express the hygrometric condition by the same degree of relative humidity. At the same time it is necessary to state the temperature of the air so that the percentage will indicate the absolute quantity of vapour held in suspension in the air. It is in all cases much preferable to state directly the weight of water contained in the air in grains per cubic foot.

At night the temperature of the air is decidedly lower than that during the day, and the percentage of humidity increases proportionately to the decrease in temperature; this is one of the reasons that dew is formed. It can therefore be seen that there will be a condensation of water if care has not been taken to reduce the hygrometric condition in a mill before stopping work at night. For example, if we take the case of a weave room that has been warmed during the daytime to 80°F, and the air humidified to 80%, the air under these conditions will contain 8.8 grains of moisture per cubic foot. Let us suppose that during the night the temperature decreases from 80°F to 70°F the air will then contain 8 grains of water per cubic foot; then will there be an excess of 0.8 grains of water per cubic foot, and these 0.8 grains are apt to condense on the walls, windows, etc. If, however, the decrease in temperature is sudden, the condensation would take place on the looms and machinery. To prevent this, therefore, it is always advisable before stopping work to reduce the hygrometric condition of the room by 0.8 grains or more of water per cubic foot of air.

Importance of Taking Into Consideration the Absolute Humidity.

It would have been a great saving of time and money to those who have patented humidifying apparatus, for instance, those in which air is circulated through showers and sprays of cold water with the object of cooling and humidifying the air, if they had made their calculations in absolute humidity instead of in percentages or relative humidity.

Question of Reduction of Temperature in Mills.

If air is circulated through a large quantity of cold water it is possible to cool the air of a room by several degrees, a most desirable result in summer, but this method, instead of humidifying the air, dries it.

For example, supposing a hot summer's day is taken with a temperature of 80°F and with 9.8 grains of water per cubic foot (90%), and supposing a spinning room has an inside temperature of 100°F. If the outside air is passed through a chamber containing a shower of water at 54°F the air will be cooled down to 60°F if the shower is sufficient. Now air at 60°F can only contain 5.8 grains of water per cubic foot, and the humidity is therefore reduced by 9.8—5.8=4 grains of water by being passed through the shower. As soon as the air enters the room its temperature is increased, whilst that of the room is decreased, say to 90°F; we then have as a result the air of the room at 90°F containing 5.8 grains of water per cubic foot; *i.e.,* 50% of relative humidity, which reading speaks for itself.

Reverting to the question of ventilation, we come to the question of the temperature in mills and the methods of reducing the same by artificial means.

Certain machines, especially ring spinning frames, give off a considerable amount of heat, and a great quantity of the heat units, transformed by the main engines into mechanical energy, are re-transformed in the rooms, so that there is a continual and considerable augmentation of temperature. It is not at all unusual in summer for the temperature of a ring room to rise up to 105° and 110°F, especially in old and badly ventilated mills.

Interdependence of Humidity and Temperature.

Ventilation by itself is not always efficacious under the peculiar conditions prevalent in the textile manufactories, in the first place because the outside air is already warm, and secondly because if the ventilation is of any importance it diminishes the humidity. If instead of making air circulate through large quantities of cold water, it was made, on the contrary, to pass through a chamber with a spray hardly in excess of the quantity of water required for saturating purposes, a considerable evaporation would be obtained by producing a lowering of the temperature corresponding to 537 calorics per kilogramme of water evaporated. Thus the difference between the outside and inside temperatures of a building that could be obtained would in reality be that indicated by the hygrometer.

Method of Establishing the Quantity of Water Required to Make Up for Deficiencies in the Atmosphere.

To establish theoretically the quantity of water required to make up for the differences between the outside and inside temperatures of a mill, the following can be taken for an example:

In summer, with a maximum temperature in the interior of a building, the air is at 86°F, and it is required to humidify for fine wools to 90%.

Now, 1 cubic foot of air at 86°F, when saturated will contain 13.2 grains of water per cubic foot, therefore at 90% it will contain 11.8 grains. If the outside temperature is at 77°F and only contains, say 41% of humidity, the absolute weight of water held in suspension will be 4.1 grains per cubic foot.

We therefore should introduce 11.8—4.1=7.7 grains of water per cubic foot of air per hour in the building, allowing that the air is renewed once every hour.

In this case it will be found that both in winter and summer the theoretical maximum amount of water required to make up for deficiencies will be approximately 7.5 grains per cubic foot.

Method of Establishing the Hygrometric Condition of a Room.

If it is required to establish theoretically the hygrometric condition of a room at a given temperature, and given the degree of saturation of the outside air—supposing the outside air is at 60°F and contains 62% of moisture, and supposing a room is heated to 70°F. The outside air will dilate or expand at a corresponding rate to the increase in temperature of 12°F.

Expansion of Air.

Now the expansion of air has been determined to be uniform between 32° and 212°F; *i.e.,* .0020361 for each degree in temperature, therefore 1 cubic foot of outside air will expand in the room to:

1 cubic foot$+.00020361\times12^\circ=1.0244322$ cubic feet. Now, 1 cubic foot of outside air at 60°F contains 5.8 grains of moisture when completely saturated, therefore 1 cubic foot at 62% will contain $\frac{5.8\text{x}62}{100}$ =say, 3.6 grains of water. This quantity of moisture introduced with the outside air will therefore occupy 1.0244322 cubic feet capacity in the room, which reduces the weight of water contained in one cubic foot of inside air to

$$\frac{3.6}{1.0244322} = \text{say } 3.5 \text{ grains.}$$

Now if air at 70°F can contain 8 grains of water per cubic foot when saturated, the inside air can only contain 3.5 grains brought from the outside, therefore the hygrometric condition in the room will be

$$\frac{3.5 \times 100}{8} = 43\tfrac{3}{4}\% \text{ of relative humidity.}$$

Thus there will be $62-43\frac{3}{4}=18\frac{1}{4}\%$ less relative humidity in the inside of the room than there is in the outside air.

Theoretical and Practical Standpoints of the Question.

Though the above examples may be of theoretical interest, from a practical standpoint they are impractical, owing to the divers complications in a mill; they may, however, be of help in showing how largely the factor of absolute humidity determines the question of "air-conditioning."

Importance of Establishing Laws on Hygiene.

To revert to the subject of ventilation, though there are no laws in the United States such as there are in European countries for the regulation of factory conditions within certain limits for the protection of the workpeople, it is unquestionably to the advantage of the mill proprietors to see that provision is made to enable satisfactory conditions to be obtained which will enable them to retain their help during the hot summer months, and at the same time preventing the sources of lessened energy and ill health. A good master makes a good workman, and a good master should see that his workpeople have good hygienic rooms in which to work, which will not only redound to their health, but also to his own personal profit.

Tendency to Neglect the Scientific Side of the Question.

Much has been said in America in favour of artificial ventilation, and there are very few public buildings, hospitals, schools, etc., today which are not installed with some method of supplying a constant fresh supply of air, and yet, in those places where ventilation is of the most vital importance, very little if anything has been done.

In my experience in the textile world I have met with two kinds of men. The one who looks on the surface and only sees the direct way of "turning a penny," and the other who looks below the surface and sees that what the first considers an unwarranted outlay of money is in reality a matter of great importance to his own pocket. The oft-repeated statement that a mill is not run as a philanthropic institution has a great deal to be said for it from a material standpoint, but when by being "philanthropic" a substantial prize is to be gained, the question resolves itself into one of dollars and cents.

Intangibility of the Subject.

I am quite aware that the subject of "air-conditioning" is one of the most intangible questions before the textile trade at the present day, and that attention has only been paid to the humidifying side of the question, as this was absolutely essential on this side of the water for successful manufacture, but though "half a loaf is better than none," I contend that ventilation is of the greatest importance, and the day will come when no up-to-date mill will be without some means of renewing the vitiated air in its rooms.

In America the atmospheric conditions have a far greater range and are more difficult to cope with than in any other textile country, and yet far more attention has been paid by the trades and legislatures of European countries to the question, and it would be difficult to find an up-to-date corporation abroad that has not one of the improved methods of keeping the conditions of their mills under artificial control; whereas in

America only one side of the question, that of humidity, has been taken into consideration, and that in a manner which, according to the majority of textile engineers and many practical American mill men, leaves much to be desired.

Artificial Methods the Only Way to Meet Requirements.

Textile factories should therefore be considered both from the humidity and ventilation standpoints, and with the many inventions of apparatus which combine these two factors there is no possible excuse why the subject should be further neglected.

PART II.

Introduction.

In the preceding pages we considered the general scope of our subject, and went more particularly into the causes and effects of electricity, humidity and temperature on textiles; we also looked at the general structure of the cotton fibre as representative of all textile fibres, and arrived at the conclusion that the "air-conditioning" problem in America was one to be considered from both the ventilation as well as the humidity points of view.

It is not a matter of great difficulty to determine what are the proper conditions for different processes of manufacture, and more information is to be found on this point than on any other relating to our problem, but the means which can artificially cause the desired effect have not been touched upon, and in consequence, though the required conditions are fully recognised as almost impossible of attainment in all seasons of the year, much ignorance is sometimes displayed on this important trade question, which, if a little more attention were paid to it, would very soon appear simpler than generally thought.

The standards as to the proper conditions for various processes and stages of manufacture for the different textiles have been reduced within comparatively narrow limits, and though different mills have different ideas, there is no great difference of opinion. The principal difference that I have found in the conditions that are considered ideal in America and those advised abroad is with regard to temperatures, and I have found that in every case that I have come in contact with a difference of from 5 to 7°F exists between the ideas on both sides of the Atlantic. As I am not a spinner, I do not venture to lay down the law on this point, but I respectfully beg to point out that if by adopting a lower standard of temperature with a higher humidity, the same results are obtained in manufacture as by following the practice of high temperatures, the help will materially benefit by the difference of these few degrees. It is very true that one often hears of the help complaining when the temperature falls below 75, and even below 80°, but a little consideration will quickly show that it is because the lower temperature is the exception and not the rule, and that if a lower standard of temperature were adopted, not only would the help become accustomed to it, and in consequence display more energy, but they would also materially benefit in health through the effect of the higher degree of humidity on "fly," dust, etc.

In the following tables, therefore, I have given the lower temperatures as practiced abroad, and it is for the practical American mill man to decide on this point for himself without any further comment on my part.

In dealing with textiles we have to consider the requirements of cotton, wool, silk, flax and jute, and a few other vegetable fibres that can be classified under one of these headings.

I have collected various data from all available sources, from talking with spinners, studying the papers read by authorities on the question, and from my own experience and observations, and in the following tables I have set down what I consider the best conditions for the various fibres.

It will be noticed that I have made no reference to silk. My reason for doing so is that my experience has been limited to the other fibres, and I do not wish to lay myself open to any controversy on the subject from those who have made a special study of this branch of the textile industries.

Theory of Regain.

The following figures have also been based on the theory that the fibres are more advantageously worked by gradually ceding a part of the moisture which they absorb during the initial processes, until they reach the weave room.

It has been my experience to have had before me the method of "air-conditioning" adopted by a certain well-known firm in Lancashire, who have on more than one occasion been commissioned to make the sails for the yachts for an equally well-known yachtsman, and it is interesting to note that the greatest importance is laid on this theory, and they even go further in liberally sprinkling the cotton before it is manipulated. This theory is much more fully recognised by worsted spinners than in the cotton trade, but it seems to me that by looking carefully into the capacity for rapid absorption of moisture by textiles, as much benefit will accrue to cotton as is the case of worsteds.

The inside of mill buildings where the initial processes of manufacture commence, even when artificially moistened, have a lower relative humidity, in the generality of cases, than that of the outside air, and the stock that is put through these departments is invariably found to lose moisture.

This subject may appear to be of little commercial importance, but I contend that it is just as easy to work as well as possible as to work well, and attention to such details as these will result in a higher standard of protection with but little or no further labour and thought entailed.

It is, of course, needless for me to point out the importance of the regain in textile fibres, and as standard conditions have been laid down by the various conditioning houses, there is no reasonable excuse for neglect in seeing that the stock contains its normal percentage of moisture on entering the mill, as when it is sent out a finished product.

Standards of Regain.

The standards of regain can be taken as follows:

Cotton	$8\frac{1}{2}\%$
Worsted	$18\frac{1}{4}\%$
Silk	11 %

Dealing first with cotton:

Conditions for the Successful Working of Cotton.

When it is remembered that cotton is grown in a warm climate, with a mean temperature of 70°F to 75°F, and then transported to a climate liable to great ranges of atmospheric changes, it will be seen that owing to the susceptibility of the cotton fibres, the unbaling, opening and scutching, or initial processes, require attention, and where the conditions are such as to divest the cotton of its natural percentage of moisture it is essential for proper working to see that provision is made for the equivalent regain.

Once the card room is reached the question of proper atmospheric conditions becomes one of primary importance.

Cards	55% humidity	72°F
Combers	60% humidity	72°F
Preparation "s l u b b ing," "drawing," "roving," and intermediate frames	65% humidity	75°F
Mule spinning for the coarser counts up to 60s	56% humidity	75°F

Mule spinning for counts from 60s to 150s	53%	humidity	77°F
Mule spinning for the finest counts from 150s upwards	50%	humidity	80°F
Ring spinning up to 10s	60%	humidity	75°F
Ring spinning from 10s to 40s	55%	humidity	78°F
Weaving light goods where very little size is required.	60%	humidity	72°F
Weaving for heavily-sized goods	85%	humidity	80°F

Worsteds:

Taking the standard condition of yarn and tops combed without oil, as 18¼% regain, as a rule 15% can be taken as a good average figure.

Preparation, fine combed wools	83%	humidity	72°F
Preparation, medium wools	75%	humidity	75°F
Preparation, common wools	65%	humidity	75°F
Wool drawing rooms	65%	humidity	75°F
"Bradford" spinning	55%	humidity	72°F
French or mule spinning	80%	humidity	80°F
Weaving	60%	humidity	75°F

Flax and Jute.

Cards	60%	humidity	65°F
Preparation	85%	humidity	70°F

Spinning..............	70% humidity	72°F
Weaving...............	85% upwards	75°F

The above figures have been based on what are considered the ideal conditions in Europe and I am aware that it is considered preferable to have higher temperatures on this side, but, as I have said before, I am of the opinion that if the right degree of humidity is maintained, the lower temperatures will be found the most advisable. If, however, through circumstances, the temperatures of the rooms cannot be governed within narrow limits, the proportions of moisture and temperature must be taken into consideration, as it is well known that yarns deteriorate if worked in too hot, at the same time as too damp, conditions, and a sliding scale must therefore be determined. The following may therefore be of some interest:

Cotton.

Preparation..	68°F temperature	68% humidity
	72°F temperature	67% humidity
	75°F temperature	65% humidity
	78°F temperature	62% humidity
	82°F temperature	60% humidity
	86°F temperature	57% humidity
	90°F temperature	56% humidity
	93°F temperature	54% humidity
	97°F temperature	52% humiditv
	100°F temperature	51% hur

Carding and average mule spinning.....	68°F temperature	56% humidity
	72°F temperature	55% humidity
	75°F temperature	54% humidity
	78°F temperature	53% humidity
	82°F temperature	52% humidity
	86°F temperature	52% humidity
	90°F temperature	51% humidity
	93°F temperature	50% humidity
	97°F temperature	49% humidity
	100°F temperature	47% humidity
Coarse ring spinning.....	68°F temperature	65% humidity
	72°F temperature	63% humidity
	75°F temperature	60% humidity
	78°F temperature	59% humidity
	82°F temperature	57% humidity
	86°F temperature	55% humidity
	90°F temperature	53% humidity
	93°F temperature	51% humidity
	97°F temperature	49% humidity
	100°F temperature	47% humidity

Worsteds.

Bradford Spinning ...	68°F temperature	56% humidity
	72°F temperature	55% humidity
	75°F temperature	54% humidity
	78°F temperature	53% humidity

82°F	temperature	52%	humidity
86°F	temperature	52%	humidity
90°F	temperature	51%	humidity
93°F	temperature	50%	humidity
97°F	temperature	49%	humidity
100°F	temperature	47%	humidity

As I have stated before, the practice of determining the temperatures and humidity differ in different countries, but as a rule the differences are so slight that there is not much to choose between them.

Opinions Passed at Various Congresses and Meetings.

At various congresses and meetings in Lille, Ghent and Mulhausen, the question of temperature and its effects on the textile fibres, has been a question of some discussion, and in each instance it has been advised that the temperature should not be less than 72° and more than 86°F. to get the best results.

Warping of Cotton.

In the warping of cotton certain remarks were made at a meeting held in Mulhausen on 30th September, 1891, on the actual procedure used in this district.

It was stated that the fraction of saturation varied a great deal, and for loose warps less humidity was required than for tight warps; 50% was the figure named for loose warps and 65% was advised not to be exceeded for tight warps.

"Conditioning."

The question of "conditioning," "setting," or "ageing" yarns and fabrics, I will treat of later, as the conditions are different to any that are required for the manufacturing processes.

PART III.

PART III.

Introduction.

IT must be remembered that in dealing with the problem of "air-conditioning" in North America, the hardest possible conditions have to be contended with, and a far more effective apparatus is required to make up for deficiencies, as also to reduce the excesses of water-vapour and heat in the atmosphere than in any other country in the world where textile industries are practiced.

In dealing with the textile districts of the United States we find that the quality of spinning varies greatly with the geographical location—the finer spinning being done almost wholly in New England.

In my tables I have mentioned five cities and districts which I consider to be representative of the conditions to be met with in the United States. They are New Bedford, Mass.; Mohawk Valley, North Central New York; Charlotte, N. C.; Atlanta, Ga.; and Mobile, Ala.

Conditions in Southern New England and New Bedford.

The atmospheric conditions in New Bedford are nearer those to be met with in Lancashire, and the relative humidity is higher than in any other of the textile districts in the United States of America, and though it is not altogether representative of the average New England conditions, I have chosen it in order that a comparison may be drawn from my tables between the fine spinning districts of Lancashire and that of the United States.

Influence of Locality.

The main reason that the finer spinning has been carried on in New England is on account of its geographical situation and the conditions resulting therefrom; its climate is noted for its changeableness, the alternations of clear and cloudy days occurring with great rapidity, and its great range of temperatures. The air can be said on a yearly average to contain 75% of relative humidity, its lowest monthly average being about 70% and the highest 80%. August and September are the most humid months, and April and May the driest; the greatest range from one month to another being about 7% from September to October.

Influence of Winds.

The influence of the winds is an important factor bearing on the changes in temperature, and as the relative humidity depends very largely on the temperatures, it will be quickly seen from the following tables the reason that southern New England holds its supremacy at the present day for the spinning of fine yarns.

During the warmer months the prevailing winds are from the S. and S.W. and these winds coming directly over the ocean absorb its moisture and at the same time by coming in contact with a cooler surface than that on land, enables the relative humidity of the adjacent mill districts to be kept at a more or less constant figure during the whole of the twelve months of the year.

The prevailing winds in winter are from the N.W. and are dry.

The mean summer temperature of Southern New England can be taken as 68°F., with a mean relative humidity of 75%, and this uniform supply of humidity can be put down to the tempering effects of the winds on the climatic conditions of the land.

Conditions in the Mohawk Valley.

The Mohawk Valley in North Central New York has been selected as having climatic features of distinctive interest. The temperatures are modified by the proximity of the Great Lakes, and the excessive cloudiness of this district have the effect of causing a more or less uniform relative humidity. The winds in this district are almost exclusively in the direction of the valley, *i.e.,* east and west.

Conditions in the Piedmont Plateau.

Charlotte, N. C., and Atlanta, Ga., are representative of the conditions prevalent on the medium elevation of the Piedmont Plateau.

The conditions of these districts show a remarkable difference in the relative humidity in February in comparison with that in December and January. The humidity falls to its lowest limit in June and the maximum is found in August. February and May are the driest months.

The climate of the Piedmont Plateau is however more settled than that of New England on account of the lesser frequency of cyclonic disturbances. The rainfall is greater but the cloudiness is less, and in consequence there are fewer rainy days. The summer winds are warm and comparatively dry.

Conditions on the Gulf Coast.

Mobile, Ala., has been chosen as a representative station on the Gulf Coast, with conditions most resembling those to be found in Southern New England. The differences being in the times of occurrence of the general distribution. The maximum humidity in this district is obtained in winter instead of in August and September. There is also a marked difference in the diurnal variations, as will be seen by referring to the tables.

Comparison Between Conditions in America and Europe.

For comparative purposes I have included centres of the European textile industries, viz.: Bolton, Bollington, Lille (as representative of Lower Flanders), also Bombay and Madras in British India.

Conditions in Lancashire.

Bolton is known as the fine spinning town in Lancashire. It is situated in a cup formed by the surrounding hills. The conditions are very cloudy and the range of temperatures very small, the summers are cool, all of which are conducive to a high degree of relative humidity with but slight diurnal changes.

Bollington, Cheshire, England, has been chosen for the reason that the finest yarns are spun there, 400s not being an unusual count. The Fine Cotton Spinners' and Doublers' Association, Ltd., have two yarn mills in this village, one of which, especially, produces the finest possible quality yarns from the best Sea Island cotton.

Conditions in Lower Flanders.

The Lille, Ghent, Roubaix, etc., districts are situated on the flat plains of Lower Flanders, and only slightly differ in degree of conditions. They are acknowledged to be the only rivals of Lancashire in so far as the climatic conditions are concerned.

Conditions in India.

Bombay and Madras have been taken in as being of interest on account of the constantly increasing development of the Indian textile trades.

Questions Governing the Superiority of Certain Districts.

It must not be forgotten that although the principal reasons of certain districts' superiority over others are mainly due to the natural climatic conditions, there are other factors at the present day, now that science has stepped in to produce artificial conditions, that must be considered where the establishment of a new mill is contemplated, viz.: the proximity of the sources of fuel and of cheap transportation, and the factors of cheap accommodation and labour.

Importance of Diurnal and Seasonal Changes, Rainfall, Etc.

The relative humidity of a locality, whether variable or constant, is dependent to a very large degree upon the diurnal and seasonal changes, the rainfall, the number of rainy days in the year, the cloudiness, sunshine, winds and proximity to disturbances of a cyclonic nature. To make a comparison between one country and another as regards its suitability for manufacturing, all the points enumerated above must be considered, and by studying the following tables it will readily be seen that those countries which are reputed for their textiles, have the better natural conditions caused by a lower range of temperature and a more regular degree of humidity, and the contrast between the ranges of temperature and humidity in the different districts in the United States, in comparison to those in Lancashire and Flanders, will be seen to give an immense advantage in favour of the latter. If America is to successfully compete with those more favoured countries, the final solution of the problem is to find the artificial means by which the conditions abroad can be obtained and maintained.

TABLE GIVING APPROXIMATE MEAN RELATIVE HUMIDITY.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
New Bedford	82	86	84	75	76	78	82	88	85	81	80	87
Mohawk Valley, N. Cent. N. Y.	70	68	67	74	75	77	77	78	80	75	76	75
Charlotte, N C.	72	62	60	57	60	59	64	73	68	67	67	71
Atlanta, Ga.	68	58	56	59	60	59	64	73	68	69	65	69
Mobile, Ala.	75	72	73	71	73	71	75	77	75	77	78	78
Bolton, Lancs, Eng.	99	88	83	79	73	73	74	89	82	86	88	89
Bollington, Cheshire, Eng.	89	88	86	82	80	79	80	82	84	85	88	87
Lille, France, and Lower Flanders generally	83	90	81	79	78	78	83	83	84	87	90	93
Bombay, India	70	69	72	80	80	82	86	87	86	80	64	70
Madras, India	72	73	74	71	75	74	70	73	77	80	89	75

AVERAGE MONTHLY MEAN RELATIVE HUMIDITY GIVING DIURNAL CHANGES, TAKING 7 A.M., 1 P.M., AND 8 P.M.

	Jan.	Feb.	Mar.	Apr.	May.	June.
New Bedford	91 67 89	94 76 89	89 73 90	80 61 84	79 62 86	80 67 87
Mohawk Valley	74 64 72	72 65 68	72 61 69	77 66 77	83 64 73	86 68 77
Charlotte, N. C.	83 62 72	75 50 61	72 47 61	69 42 61	72 45 63	64 45 59
Atlanta, Ga.	76 61 68	68 49 58	68 47 55	69 49 52	71 48 62	69 47 61
Mobile, Ala.	85 63 77	83 57 76	86 55 77	80 56 77	83 57 79	80 57 76
	July.	**Aug.**	**Sept.**	**Oct.**	**Nov.**	**Dec.**
New Bedford	86 70 90	91 75 91	88 72 88	89 69 86	90 66 83	90 77 89
Mohawk Valley	85 68 80	87 68 80	88 70 81	82 66 77	81 70 78	77 71 74
Charlotte, N. C.	79 51 72	81 62 76	81 52 71	80 51 71	79 54 69	81 60 72
Atlanta, Ga.	74 52 66	84 60 76	79 55 69	79 58 71	76 55 64	79 60 68
Mobile, Ala.	82 63 81	92 59 89	86 59 81	85 63 84	85 61 81	84 69 80

DAILY RANGE OF RELATIVE HUMIDITY.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Yrs.
New Bedford	23	19	17	23	24	20	21	20	16	19	23	14	20
Mohawk Valley, N. C. N.Y.	8	9	9	11	15	14	16	17	19	17	10	6	12½
Charlotte, N. C.	21	25	26	27	26	23	25	22	28	29	25	22	25
Atlanta, Ga.	17	19	22	20	23	22	21	25	24	21	20	18	21
Mobile, Ala.	23	26	30	26	27	22	18	32	29	26	24	16	25

AVERAGE MONTHLY MEAN TEMPERATURES.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Yrs.
New Bedford	28	29	35	44	55	64	70	68	62	52	42	32	48
Mohawk Valley, N. C. N.Y.	22	23	29	42	55	64	70	68	62	49	37	27	—
Charlotte, N. C.	42	46	50	60	69	76	79	76	71	61	51	44	60
Atlanta, Ga	43	48	52	62	69	76	78	76	72	62	52	45	61
Mobile, Ala	51	56	60	67	74	81	83	81	78	68	57	53	67
Bolton, Lancs, Eng	37	40	39	44	49	58	59	58	55	47	43	37	47
Bollington, Cheshire, Eng.	34	37	39	46	50	57	58	57	53	45	41	37	46
Lille, France, and Lower Flanders	34	35	36	45	51	62	67	68	60	47	42	35	—
Bombay, India	73	75	79	83	85	83	81	80	80	89	79	76	80
Madras, India	76	77	81	85	87	87	85	84	84	81	78	76	82

PART IV.

PART IV.

Introduction.

My main purpose in writing these pages was not to go into the details and principles of hygrometry and generally of the mechanics and chemistry of air and water, so much as to describe the evolution of the present day up-to-date processes and apparatus by which artificial conditions for successful manufacturing can be obtained.

The booklets published by the late Sir Benjamin A. Dobson on "Humidity in Cotton Spinning," and lately re-published in one volume by Mr. W. W. Midgeley, F. R. Met. S., deal with the scientific side of the relations between air and water in the atmosphere so fully and so correctly as to render any detailed reference to this side of the subject superfluous on my part, and although I have included in these pages a short exposé of generally admitted facts, my efforts have been more in the direction as to what has been done to obtain the theoretical desiderata with regard to suitable conditions, and if, therefore, any of my readers wish to increase their knowledge and to supplement the information in this work on the purely scientific sides of humidity, temperature and hygiene, they will do well to consult Sir B. A. Dobson's work, which deals with each question in detail, and which to my knowledge is the only authoritative and complete work that has ever been published on this question.

My purpose has also been to endeavour to open the eyes of the American textile trade to the fact that other methods than those practiced in this country have been bought out and are in operation abroad. Methods which more nearly approach the ideal conditions of natural evaporation of water by air, than anything that has yet been done in the United States of America.

Early Days.

In the early and pre-scientific days the recognition of the importance of suitable conditions was shown by the centralisation of the textile industries in those countries and districts where those conditions were to be obtained. It was due to these natural conditions that British textile industries have for so long held the supremacy over all other countries, and which have been rivalled only by the textiles of Lower Flanders. Even to-day, though the problems of manufacture are complicated by new and improved processes, the majority of mills producing the coarser yarns in Lancashire rely on the natural atmospheric conditions, without supplementing them by artificial means.

Old Mill Buildings Versus New.

It is true that the old mill buildings in Lancashire are peculiarly suitable to the retainment of humidity; the walls are thick, the rooms low-pitched and small, and the windows small; and the floors and woodwork generally are so saturated with years' accumulation of oil, that this condition alone is almost sufficient cause for the retainment of moisture. In modern mills since steel has so largely entered into building construction, the walls are not so thick, the rooms are much larger and higher pitched, and the windows very large, and it has been found necessary in the majority of cases to instal some efficient system of "air-conditioning." The same is applicable to the continental textile industries centered around Lille, Ghent, the Vosges, etc., etc., and the number of patents taken out dealing with humidifiers show the importance with which the question has been looked upon.

"Degging" and "Steaming."

We can therefore start our subject from the point of natural climatic conditions. In certain mills on certain days in the year, owing to some slight deficiency in the atmosphere, the operatives are in the habit of sprinkling the floor with a watering can, or as they call it, "degg" the floor. This primitive method, though sufficiently satisfactory where only small deficiencies have to be made up, cannot be satisfactorily practiced in cases where a high and constant degree of humidity is required, and the practice of "steaming" or blowing-off live steam became general in both spinning rooms and weave sheds, until this method of moistening, combined with insufficient ventilation of the old type of mills, was found to be detrimental to the general health and comfort of the operatives.

Cotton Cloth Act.

When the Cotton Cloth Factories Act of 1889 was passed with the intention of regulating the conditions under which artificial humidification should be applied, this method was condemned, and now though many of the older mills in Lancashire still make use of this method, they have been obliged to ventilate their sheds by means of fans to comply with the factory regulations.

Primitive Devices.

Before mechanical methods were adopted, many devices were experimented with, with the object of obviating the necessity of steaming. Most of the experiments and devices originated from practical mill men, who tried them in their own factories. The general principles, though not being incorrect, the applications were much too crude for much benefit to be derived.

These devices were based on the fact that if the atmosphere of a room could be moistened by evaporating the water that was sprinkled on the floor, that by having large and constantly moist surfaces in the room, the same result could be attained with considerable saving of labour and time.

These devices were of two types, the first relying solely on the natural evaporation of water by air, and the second supplementing the effect by quasi-mechanical means.

The first method consisted in having channels built into the floor with a slight drain towards one side or end of the room or shed, the idea being that the porous bricks with which these channels were lined would absorb the water which was made to flow along the channels and cede it by evaporation to the air of the room.

These channels were either placed at the sides of the room or lengthwise down the centre, and in some cases were even built directly under the machines or looms.

This method was especially adopted in weave sheds and ground floors generally, but was condemned owing to the bricks and the interstices in between them accumulating the dirt and "fly" from the floor, not only necessitating much labour in cleaning, but if this was long neglected the risk of causing effluvias pernicious to the health of the workers. There were also other general practical objections.

The same principle of having large evaporating surfaces was tried with more success in the case of the upper rooms. Shallow metal pans were placed on the same plan as the channels, either on one side of the room or under the machines. This method was later improved upon by suspending the troughs over the steam-heating pipes, the radiating head of which had a tendency to increase the natural evaporation.

This method of aiding natural evaporation was further improved upon by placing steam pipes directly in the troughs and in some cases heating the water up to as high as 150°F., and in winter the added heat not being objectionable, the system met most of the requirements. In summer, however, the heating of the water was inadvisable for obvious reasons, the natural evaporation from the surface of the water not being sufficient, the results were found to be incomplete.

Further reference will be made to this method in the following pages.

The objections to these systems of evaporation troughs were principally owing to the inadequacy of the systems in summer, and the time required to regulate the humidity to meet the changes of the outside atmosphere, and thirdly, the size of the troughs when made to present the large surfaces to suit the requirements of large rooms.

The foregoing methods are the only ones that I know of which have been experimented with, with the idea of ultilising the principle of natural evaporation without mechanical means.

These pre-scientific methods being found to be unsatisfactory, it was left to the ingenuity of textile engineers to invent a means whereby the dry atmosphere of the rooms could be made to absorb the requisite amount of moisture with rapidity and ease.

It was seen that if air could absorb water when splashed over the floor, the absorbing capacity could be very much increased if the water were broken up into minute particles, presenting a very large evapora-

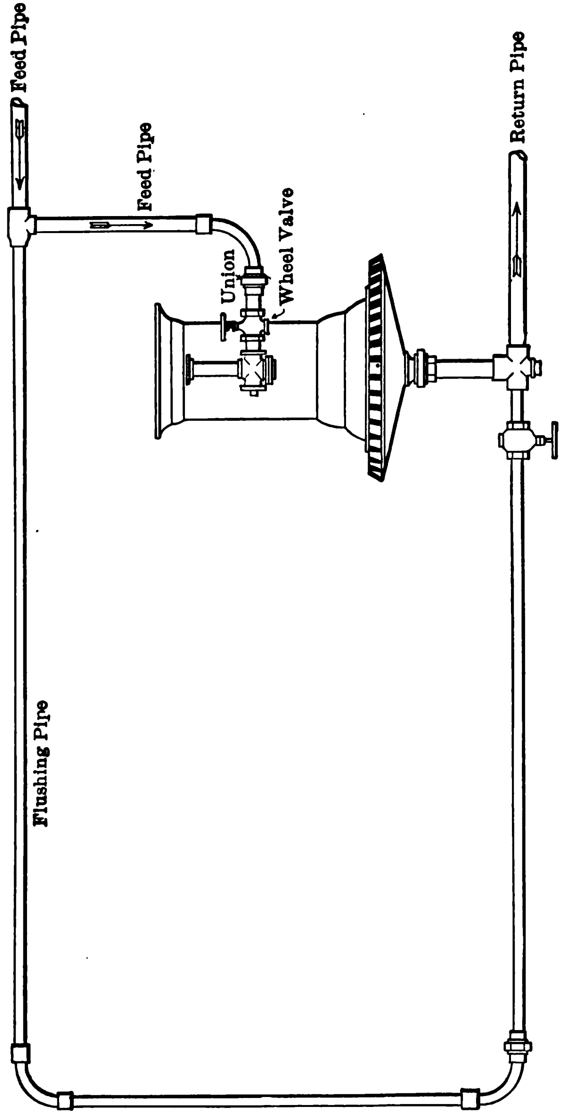

FIG. 1.—A WELL-KNOWN DESIGN OF "HEAD" HUMIDIFIER, SHOWING SYSTEM OF PIPING, ETC., ATTACHED.

tion surface, and from these observations was evolved what is known to-day as the head type of humidifier.

Head Type of Humidifiers.

At first this style of apparatus was very crude and much worry and damage was caused by the fact that the water issuing from the machines was in many cases insufficiently pulverised, the larger drops falling on the operatives and machinery, with consequences that need not be mentioned. As time went on, however, the mechanism of the apparatus became so ingeniously improved that not only was the cost of upkeep, cleaning, etc., reduced to a low figure, but the spray was delivered in such a state of fineness that very little was to be feared from drops or condensation.

This type of humidifier is almost too well known in the United States to require much explanation. It can roughly be divided into two classes, technically termed the "single jet" and the "double jet."

Description of the "Head" Machine.

Although this type of humidifier is so well known, this book would not be complete if a description were not given.

The system of heads consists in placing at intervals, and at a certain height from the floor, a number of "humidifiers" connected with feed and return pipes. These "humidifiers" are supplied with water under an approximate pressure of 100 to 125 lbs. by means of a suitable pump drawing the water from a tank. The water, which can be either warm or cold, is admitted through a feed pipe, regulated by a ball-tap, into the tank, from which it is sucked into the pump and thence delivered to the humidifiers, the waste returning to the tank, where it is filtered by suitable means.

The humidifiers proper are made in the majority of cases of this type to have a double function.

Firstly, to send into the surrounding air a finely pulverised spray so as to fill with moisture the spaces in between the "heads."

Secondly, to keep up a constant circulation and washing of air, by inducing the hot, dry, vitiated air that rises to the top of the room, into the body of the humidifier through its upper portion, and to expel it through the lower portion, charged with vapour.

By dispersing hot or cold water from the machines it is claimed that a certain amount of cooling or heating is effected.

The effects claimed are obtained by either the "single" or the "double" jet.

The "single jet" or nozzle arrangement consists of the feed water passing in the first instance through a filter attached to the side of the cylinder head, with the object of retaining and catching any dirt which has escaped the tank filters. From the filter the water passes into the nozzle, from which it is expelled at a pressure ranging from 100 to 125 lbs. per square inch, in a straight jet, impinging directly upon the end of an adjustable pin. The result is that the jet of water is split up into a species of hollow cone, which causes the vacuum that induces the air through the upper portion of the cylinder, and this air becomes charged with minute particles of water, escapes into the room through the lower portion of the apparatus.

The "double jet" arrangement is similar in design to the above, with this difference, that instead of a single jet of water impinging on a cone or pin, two jets impinge on each other, the lower jet taking the place of the pin.

The condensation and clogging up of the nozzles, etc., which caused so much trouble at the beginning, have been almost entirely overcome by the development of the mechanism.

The filters attached to the cylinder, which in the first years often required taking out to be cleaned, and which often resulted in neglect on the part of the attendants, have now been replaced by self-cleaning filters of ingenious design. These filters are flushed only when the plant is started or stopped, and all "fly" or solid matter that has accumulated during work is washed away by a flush of water under a high pressure. This water flows back to the tank through the ordinary return pipes.

The feed and return pipes are made of ample capacity so as to eliminate the danger of clogging up by the accumulation of dirt which may find its way into them, and to keep these pipes quite clear, up-to-date installations have been fitted with a flushing arrangement. This consists in connecting the terminals of the high pressure feed pipes with the low pressure return pipes, and by opening a valve on this connection or bye-pass, the return pipe system is flushed by the high pressure stream from the pumps.

The tank and pump necessary for the working of the head systems should be located in as central a position as possible, and as they do not occupy much space there is no great difficulty in meeting this re-
the above cut by means of a duct A. B represents a
quirement. The water to be employed is admitted into the tank, a ball-tap regulating the feed pipe. The water on its passage to the pump is passed through a filter, and all the water that comes back through the return pipes is passed through another filter or straining basket in the tank.

There have been a great number of patents taken out in connection with this type of humidifier, each differing in some detail, but all agreeing in the principle of spraying directly into the room and placing the heads at intervals and at a certain height from the floor. The following cut shows a representative installation of this type of machine.

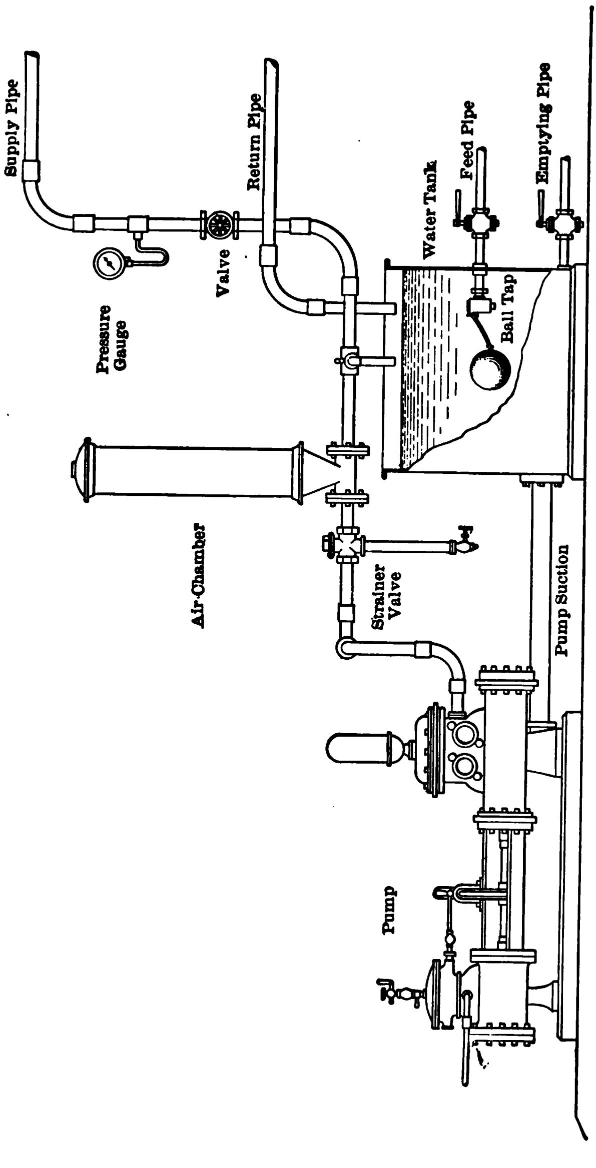

FIG. 2.—PUMP, TANK AND PIPING USED IN THE "HEAD-TYPE" INSTALLATION DESCRIBED.

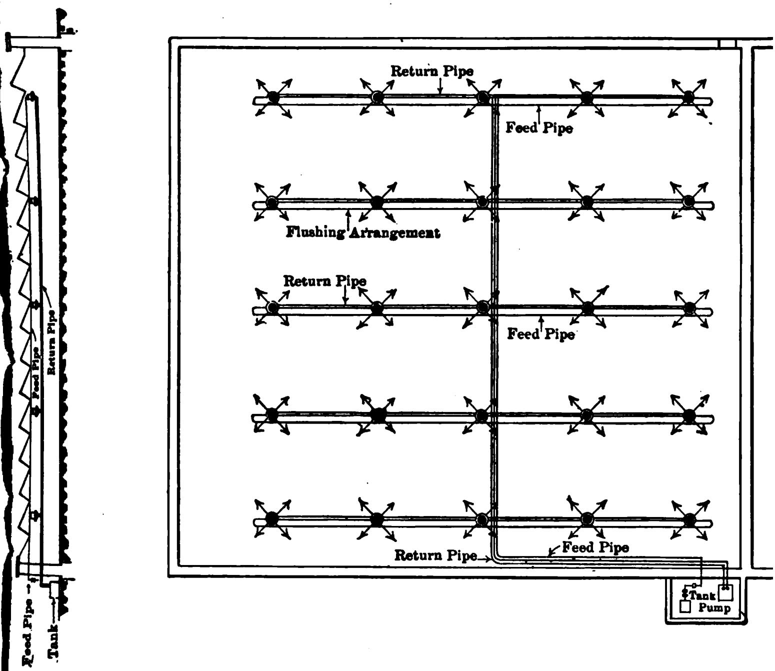

FIG. 3.—"HEAD-TYPE" INSTALLATION.

Most of these patents and inventions have been secured by the large firms of humidifier makers, and those that have not been bought up are not of such importance as to require a detailed description. The principal makers of the head type of humidifier in Europe are as follows: Mather & Platt, Ltd., the "Vortex" (late Dowson & Taylor); Hoffman or "Drosophore," Manchester, England; Emil Mertz, Bâle, Switzerland.

In America the rights secured by the American Moistening Co., of Boston, seem to cover the field for this type of air moistener.

In Europe the close connection between humidification and ventilation has long been recognised, till it is no longer considered necessary to contend that a system of humidification is complete unless combined

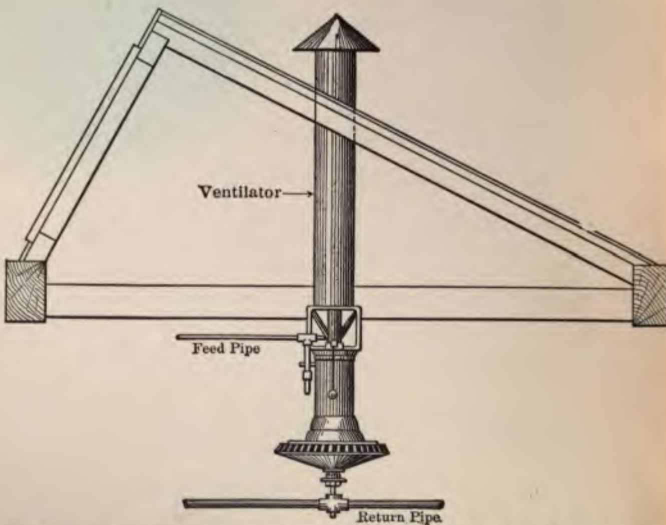

FIG. 4.—"VORTEX" "VENTILO-HEAD" HUMIDIFIER.

with ventilation, and humidifier makers of the head type now combine a fan in the top of the cylinder of the machine, communication directly with the outside air, either by means of a duct through the roof or through the windows.

The partial cooling of the induced air in summer is effected by its passing through the spray of cold water in the back of the humidifier, whilst in winter the air is drawn from the room or from the outside, and regulated by means of dampers and heated by the use of warm water.

It is sometimes the practice in such an installation to provide means of extracting the vitiated air; this is accomplished by means of extraction fans fitted into the windows.

The success of an installation of head humidifiers depends largely on the conditions under which it is installed. The space in between the heads have to be approximated sufficiently that the effect of each head may not be localised, and on the approximation and number of heads the best working of such an installation largely depends. It is therefore advisable to have a surplus of heads in order that the hygrometric degree may be as even as possible.

I have found the practice to be to count one head for every 14,000 to 25,000 cubic feet of cubical contents of room heated, according to the nature of the room, but in my opinion the latter figure is not to be advised.

In the case of the ventilo-head type, the distribution of the humidity is materially helped by the currents of air produced by the fans, and this type of head installation is far preferable to the former.

It is claimed that each ventilo-head can deal with from 25,000 to 35,000 cubic feet of fresh air per hour.

A humidifier that was much used a few years ago in the flax mills of Ireland consisted in a fan inducing the air from the outside and delivering the air into a scoop or cone in which was placed a steam jet.

This humidifier is still in use in the older mills around Belfast, Ireland, and in some of the weave sheds in and around Burnley and Colne, Lancashire, but it is being replaced by improved types of ventilo humidifying apparatus.

Keith-Blackman.

A type of humidifying system that has been installed in a few instances abroad is the Keith-Blackman system, its equivalent in many respects in America being the Garland system.

This system consists in placing at intervals in a room, very fine atomising nozzles, connected to a system of feed piping, through which water under a high pressure is forced.

The system, in method of outlay, is similar to the head type, and fans are arranged, fitted into the walls as in the ventilo-head humidifier systems, but as the efficiency of the system depends chiefly on the fineness of the spray, and as the nozzles are very small, there is a risk of clogging.

During recent years several systems of ventilo-head humidifiers have been put on the market, systems differing from the above mentioned types in that the means of humidifying is different, although in principle the two types are similar.

Hart.

The "Hart" system (J. A. Hart, of Blackburn, Lancs., England), consists in a head of much larger capacity than the above mentioned types. (It has been especially applied to weave sheds.) The distribution depends almost entirely on the currents of air delivered by the fans. (See cut of Hart.)

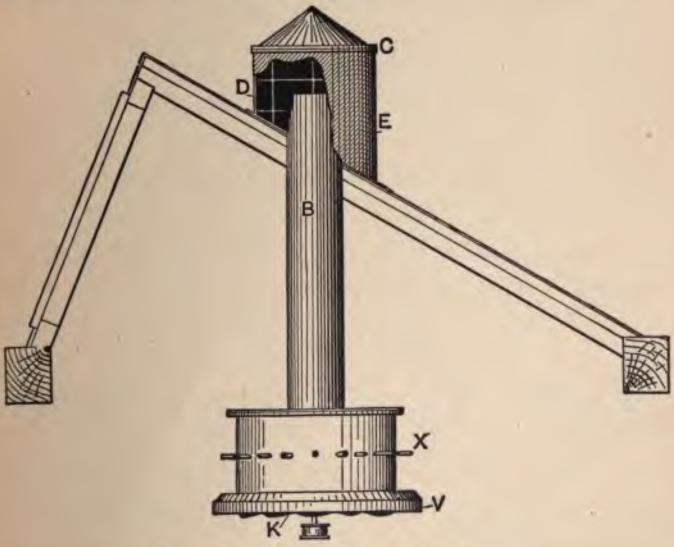

FIG. 5.—"HART" HUMIDIFIER.

The fan is connected to the outside air as shown in duct and C is a circular trough; D represents a frame-work which supports the trough. Water is fed into C and wets the matting E, the upper edge of which is turned into C. Fresh air is drawn through E and is thus cooled and humidified in hot weather, and then passes down the duct B into K. The fan K discharges the fresh air mainly through the perforated zinc cage or drum O, and a small percentage through the jets X, and so divides the fresh air into radiating streams into the room. Inside the duct B is fitted a heating coil. V is a large steam ring humidifier for use in cold weather, which moistens the air with atmospheric steam.

This system is sometimes supplemented by exhaust fans, fitted into the windows of the room to withdraw the foul and dusty air.

There have been and are several systems put on the American market that seem to have much the same principles as the Hart system, *i.e.*, ventilo-heads of relatively large capacity. They are as follows:

The Bell System.

This system differs in its application in that the damp cloths are directly in the room and the air of the room is re-circulated through them. It would, however, be possible by supplying ducts to take the air from the outside.

The Regenerative Cold Air Co., Late of Boston.

This system consists of ventilo heads, with the fans placed in the same way as the Hart system, *i.e.*, at the bottom of the apparatus, but exhausting the air directly through a shower of water, hot in winter and cold in summer, which is sprayed over concentric plates so as to form a large evaporative surface. The water is drained away by a drain pipe connected to a small tank and pump attached to each individual head, which re-circulates the water.

All the above systems of "heads" or "ventilo-heads" have the same rules of application and can be summarised as the "head type" humidifiers. They have all the same quality of being placed at intervals in a room and at a certain height from the floor.

Central Type.

The next type of humidifier I propose dealing with, and one that has met with its complement of votaries, is the "Central" type, *i.e.*, a system of ducts, either built in the masonry and buttresses of a mill, with delivery outlets into the various rooms, or else galvanised iron ducts leading into the rooms from the sides or centre as may be convenient. This system of ducts is connected to a large centrifugal fan, placed in a suitably central position, sucking the outside air over a battery of steam coils for heating in winter.

Such systems claim to heat, ventilate and moisten an entire mill from one central point; the humidifying being done by introducing steam into the main ducts, which is carried into the branches and thence into the rooms.

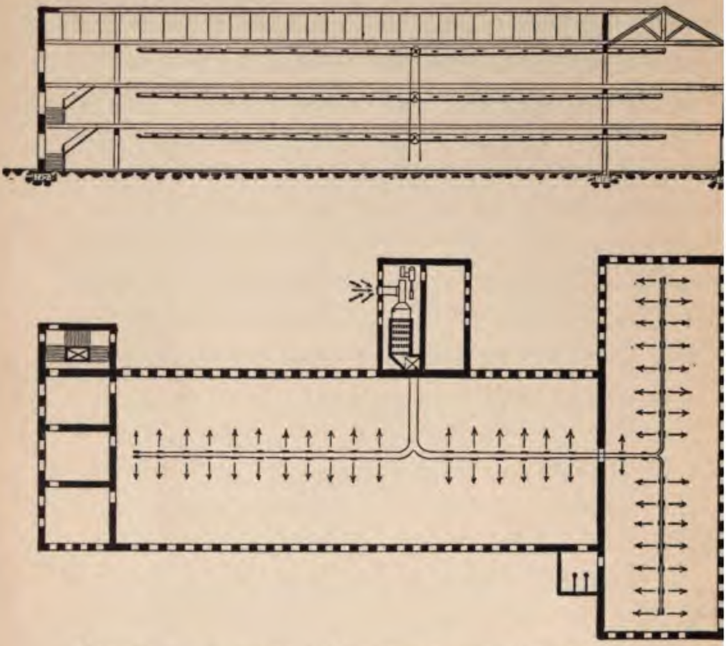

FIG. 6.—A TYPICAL "CENTRAL-TYPE" INSTALLATION.

The points embodied above have been adopted by the Sturtevant Engineering Co., of Hyde Park, Mass., and the Buffalo Forge Co., of Buffalo, N. Y.

Parsons.

Another system which can be termed a "central" system is that of Parsons, Blackburn, Lancashire, England, but the application has generally been to distribute the air into the mill by means of distributing ducts suspended from the ceilings, and at a certain height from the floor, with branch pipes leading from the main duct into all parts of the room or rooms. In principle it is the same as the above mentioned systems.

We now come to the third class of apparatus, a type of machine that is based on the principle that to get the best results each room of a mill has to be treated separately by an individual installation.

This class of systems includes in nearly every case centrifugal or cased fans, as being the only positive means of forcing the humidified air through the distributing ducts in all parts of the room. The installations, excepting in the case of very small rooms, include more than one fan, in some cases of very large rooms and sheds as many as 15 to 20 separate plants are installed, each dealing with its own part of the building.

The inventors of these systems claim that this method is the only one whereby the degree of humidity can be evenly distributed over the whole room. Their arguments in defence of this being that when steam is not used, the long lengths of duct and branches attached to a fan of inadequate capacity cannot carry the air at the same degree of humidity throughout their whole length, and that the pipes have to be restricted within certain limits of lengths for the desired results to be attained. Their argument is that where sprays of water or humidified air in the first sections of the duct system are sufficient, the mist of water is unable to be carried by the current of air in the farthest sections, and where humidified air is delivered by the fan, the air gradually gets drier the further it gets away from the fan, owing to the temperature of the room affecting the surface of the ducts, and heating and consequently expanding the currents of air which have not the velocity to be independent of these effects.

The systems in this class can be sub-divided into three divisions:

(1) Humidifying the air before it reaches the fans.
(2) Humidifying the air after it leaves the fans.
(3) Humidifying the air in the fans.

The following systems can either be included in one of these sub-divisions or else embody one or more of the principles:

Roger Pye, Blackburn, Lancs., England (2).

Matthew & Yates, Swinton, Lancs., England (2).

Hall & Kay, Lancs., England (1).

Howorth & Co., Moses Gate, Lancs., England (1 and 2).

Koerting, Germany (2).

Kestner, Lille, France (2 and 3).

Pye or "Unique."

The "Pye" system is still in use in many weave sheds in Lancashire and also in some Indian mills, but the firm is no longer in existence. Like all systems of this type the installations include one or more fans, sucking the air from the outside. The "Unique" Humidifier and Ventilator (as it was called) consists of a mixing, cooling, heating and moistening chamber, lined with porous tile pipes.

The fans deliver the outside air (or inside air as is desired) into this chamber, which encloses a steam injector, gun-metal cases, water sprayer, and steam and water valve, so arranged that the current of air can be reversed, converting the machine into an exhausting ventilator, when required. To this chamber is connected the system of ducts.

The branch pipes are fitted with slot holes and slide doors on each side alternately, about every three feet, with hand holes in the mains and branches for cleaning purposes.

Matthew & Yates, "Cyclone" Humidifier.

This system comprises fans exhausting the outside air (over spirals of steam coils for heating in winter), and delivering it into the distributing trunks in which steam and water jets are fitted inside at the junction where the pipes join the blowers. As in the "Pye" system, slot-holes and slide doors alternate on each side of the ducts. Any condensed water that forms in these ducts is carried away by drain pipes attached to their extremities.

Hall & Kay, "Patent Fresh Air System."

This system has had more than one application, and various improvements have been from time to time added to it.

In one of its applications the principle is on the open water trough system, already described, supplemented by the introduction of fresh air. Evaporation troughs of suitable size are suspended from the ceiling, the troughs being made of tinned copper or other metal. Outside of these an outside casing is fitted, having an interspace for the circulation of the air.

The fresh air is introduced at one end of this arrangement of troughs from the fan ducts, and passes out through small vertical diffusers directly on to the water in the inner trough, and thence the air is diffused into the room charged with aqueous vapour. When necessary, steam is passed into a copper pipe placed inside the water trough, to increase the evaporation by heating the water. The level of the water in the troughs is maintained by ball-taps.

As in the other systems, the air is distributed through the system of troughs by a blower, which takes the air from the outside or inside of the mill, as desired.

The following sketch shows the general arrangement of such an installation.

Messrs. Hall & Kay now make the troughs wider to expose a greater evaporative surface and to dispense with the steam pipes for heating the water, and also attach a "filtering or humidifying" apparatus to some of their installations.

It was found that the air taken in by the fans for distribution in the room, in dull, foggy, winter weather,

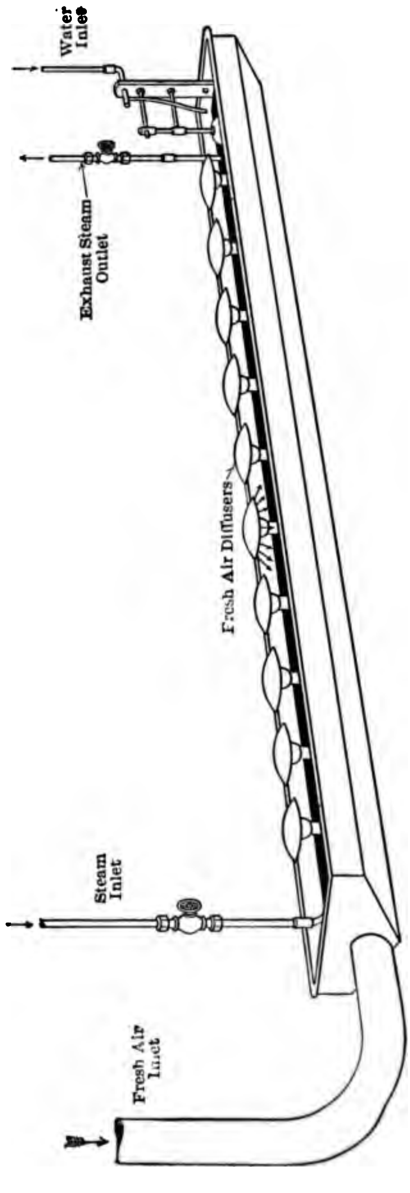

FIG. 7.—HALL & KAY'S HUMIDIFIER.

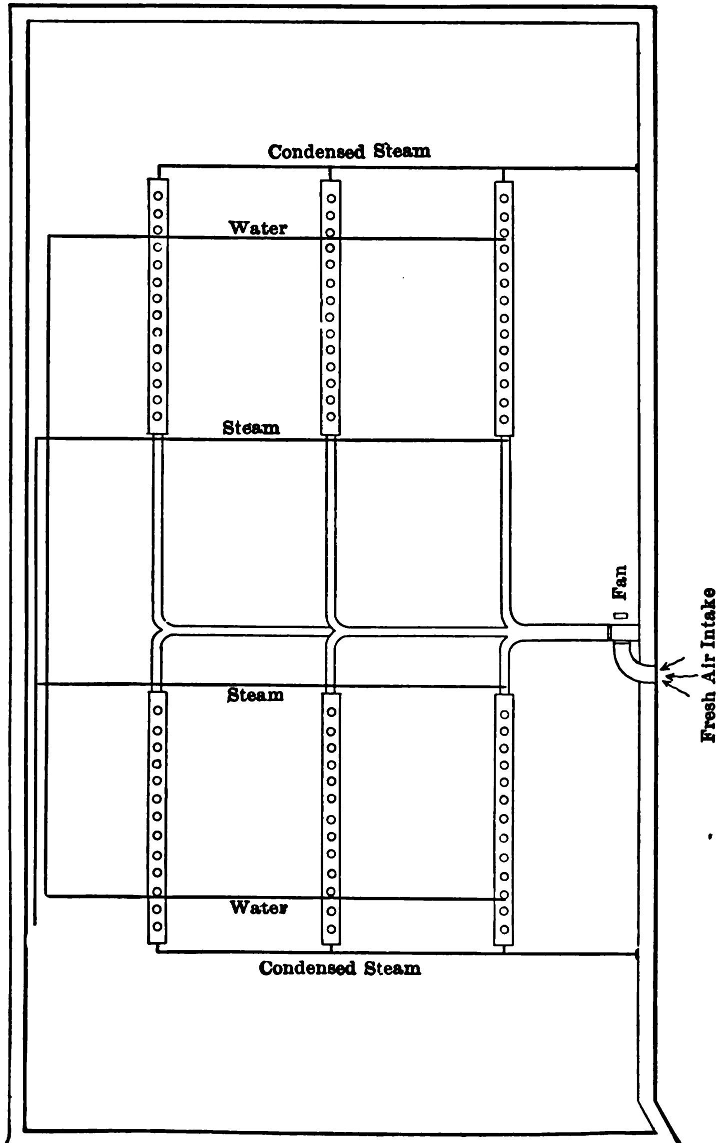

FIG. 8.—INSTALLATION OF HALL & KAY'S HUMIDIFIER.

when the air is charged with smuts, that the cops and rovings become soiled, and to overcome this the apparatus shown below was devised to purify and at the same time humidify the air.

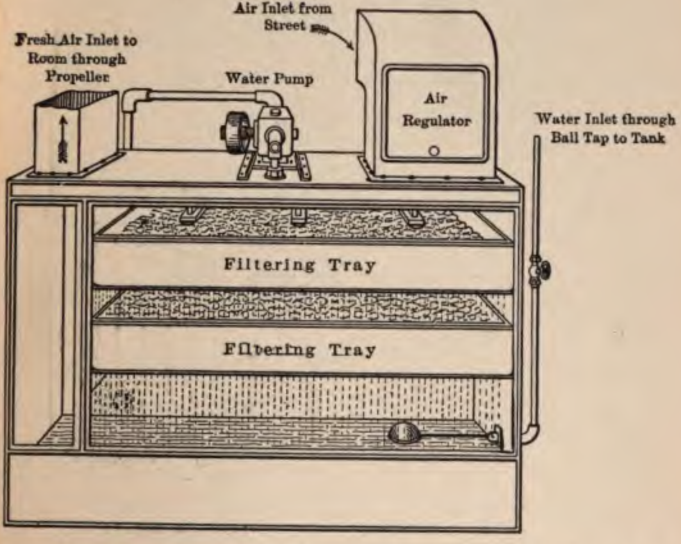

FIG. 9.—HALL & KAY'S FILTER AND HUMIDIFIER.

These filters fit into the recesses beneath the mill windows. Fresh air is sucked in through inlet connecting to the outside through the window. The opening is connected to the fan. Inside the filter a zinc case is fitted with a horizontal perforated tray or trays, containing several layers of loofah, asbestos, or other filtering material. This material is kept constantly soaked by means of the water sprays supplied by the pump.

The air being drawn through the filtering material becomes cleansed and moistened and is in this state delivered by the fans into the distributing ducts.

Latterly, in cases where the mills are situated near coal yards or in very unfavourable situations where there are large quantities of floating coal dust, smuts or soot, dry filters have been added.

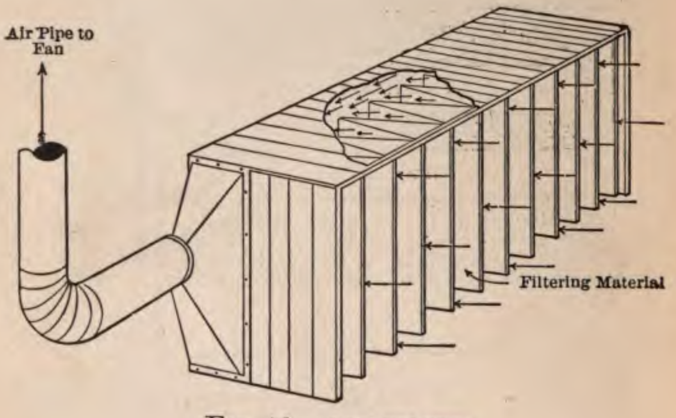

FIG. 10.—DRY FILTER.

These filters consist of a large expanse of flannel or other suitable material, stretched over a frame-work in accordion fashion, thus forming a very large surface to eliminate undue resistance. The smuts are collected by this flannel and the air then goes to the wet filter and humidifier.

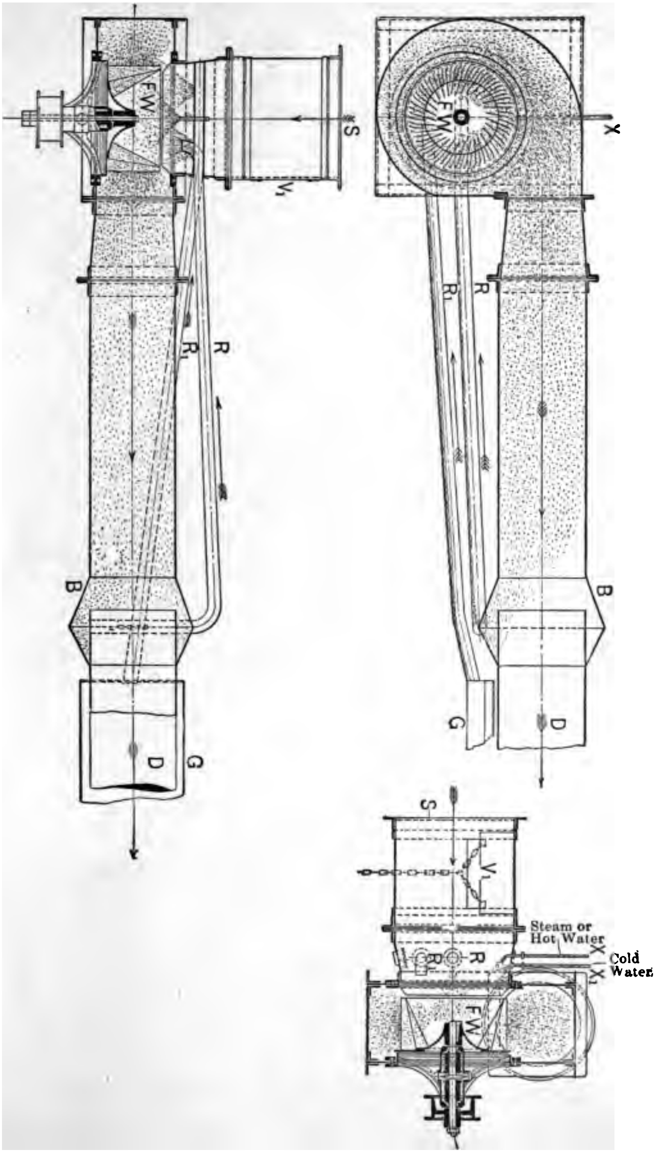

Fig. 11.—KESTNER "ATOMISER" FAN.

Howorth & Son, Bolton, Lancashire.

This firm have more than one system on the market. In the earlier applications the Howorth system was more after the type of the "Central Type," and consisted in distributing from one central point the humidified air through long systems of piping.

The fans in the earlier days were not of the blower or centrifugal pattern, but were of the "disc type," enclosed in a metal casing. The air was sucked in the ordinary way from the outside (over steam coils in winter) and sucked either through a spray-chamber or else blown through a chamber containing a revolving brush arrangement partly submerged in a tank of water; the "brush" revolving in the water created a spray and the air passing through this became moistened.

The other Howorth systems are based on the same principles of combined humidification and ventilation, the moistening being obtained by means of spray chambers and the ventilation by means of blowers in the place of "disc" fans.

The Koerting System.

This system is to all intents and purposes a central type system, but is also applied to each room separately. It consists of a blower fan sucking the outside air through a spray chamber or blowing the air through the same. The ducts can be arranged in the same method as in the other systems.

I have not gone into much length in describing these various systems, as they are all based on the same principles of spray chambers, or filters, and though differing in mechanical details, these are hardly of sufficient importance to warrant my going into a more detailed description.

The Kestner System, Lille, France.

This system, though combining ventilation and humidification in the same plant, radically differs from the others in that it is also based on what has been called the "sur-saturation" principle, *i.e.,* mantaining a state of fog, mist, or, in other words, a sur-saturated state inside the whole of the duct system.

In the first applications of the Kestner system, the air was drawn through a spray chamber, as in the above described systems, and delivered into the room through distributing trunks and drawn across the room by a system of suction ducts attached to the suction end of the fan. The amount of inside or outside air exhausted by the fans being regulated by the dampers.

In the latest types of installations these suction ducts have been done away with, the air still being taken from the inside or the outside of the room as described, but at a point near the fans.

The "sur-saturated" state of the air in the ducts is obtained by means of a specially constructed fan, which is essentially a pressure blower. After the spray chambers were done away with, a jet of water was introduced into an ordinary type of blower fan, and broken

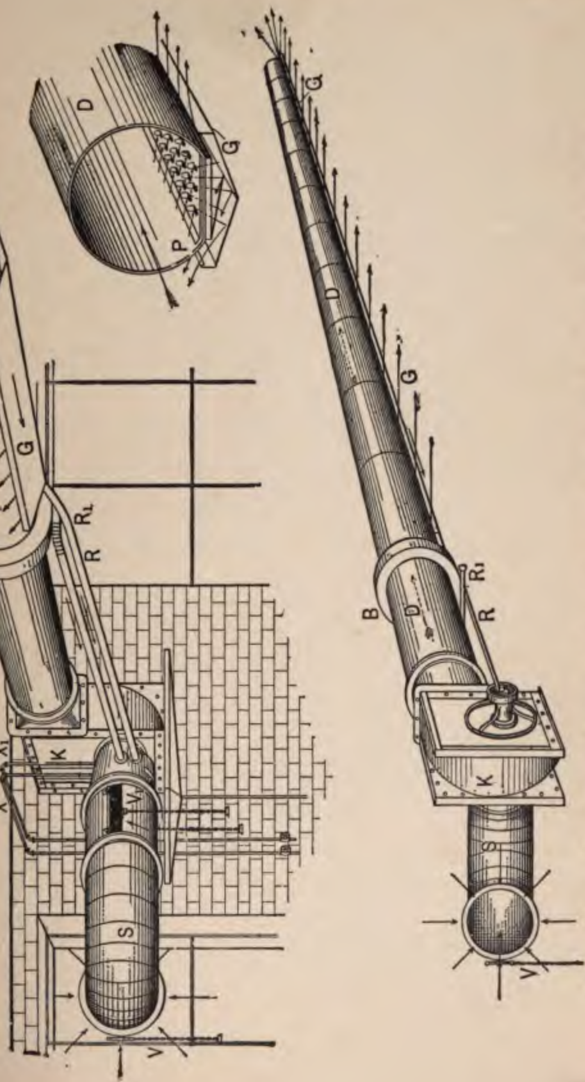

Fig. 12.—"Kestner" System, showing Details of Delivery Ducts.

up into spray by the rapid revolution of the fan-wheel vanes. It was found that by increasing the number and shape of the vanes and making them revolve at a high speed, the "atomising" of the water was increased in proportion to the number of vanes and the rate of speed, and at the present day these fans have been so improved, and the lengths, tapers and diameters of the pipes so calculated, that the mist created by the fans is so fine as to be carried by the currents of air created by the fans throughout the whole length of the pipes.

The delivery ducts contain along the whole length of their undersides a number of perforated removable doors or "grids," the taper of the pipes and the number of holes in the grids being calculated so that the velocity of the air as it issues at all points of the ducts is as even as possible. Underneath these grids is placed a V-shaped trough to catch the condensation and heavy drops of water which collect in the duct, and the troughs having a slope back towards the fans, the water is carried either back into the fan or drained into a tank and pumped back into the system, thereby avoiding all waste of water.

It is claimed that by means of this "sur-saturation" principle, the required degree of humidity is more quickly obtained than by any other method, and that the cooling effected in summer is more efficient, seeing that the evaporative surface is very great.

By means of this system, filters are eliminated, as the atomiser fans are in themselves most efficient filters and the application in most adverse conditions tends to prove the truth of this statement.

In these systems combining ventilation with moistening, the ventilation is in nearly all cases on the "plenum" system. This "plenum" or pressure of air has a two-fold effect; in eliminating the draughts or smells coming into the room from the outside, and in forcibly distributing the humidified air in such a manner as to maintain as even a degree of humidity as possible.

Various Apparatus.

There are many means of moistening the air of mills which have been devised by the mill owners or superintendents themselves, all having points of merit and interest. The following method is employed in a certain well-known Lancashire cotton mill, which is built on the shed principle, *i.e.,* with the carding, preparation and spinning processes all taking place in one large shed, and although the possibility of obtaining varying degrees of temperature and humidity for the various processes is rendered more difficult, it is claimed that the advantages of eliminating stair-cases, elevators, etc., compensate for this.

The shed is built on piles, with an interspace between the floor and the soil. The pillars supporting the shed roof have been specially constructed in a square form with openings at or about six feet from the floor level,

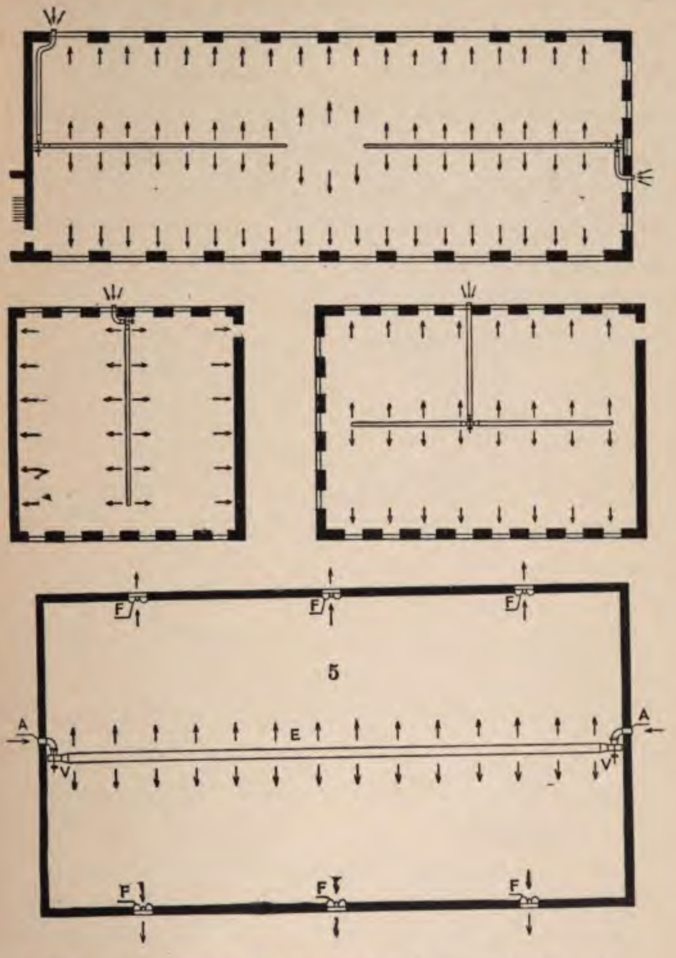

FIG. 13.—TYPICAL "KESTNER" INSTALLATIONS.

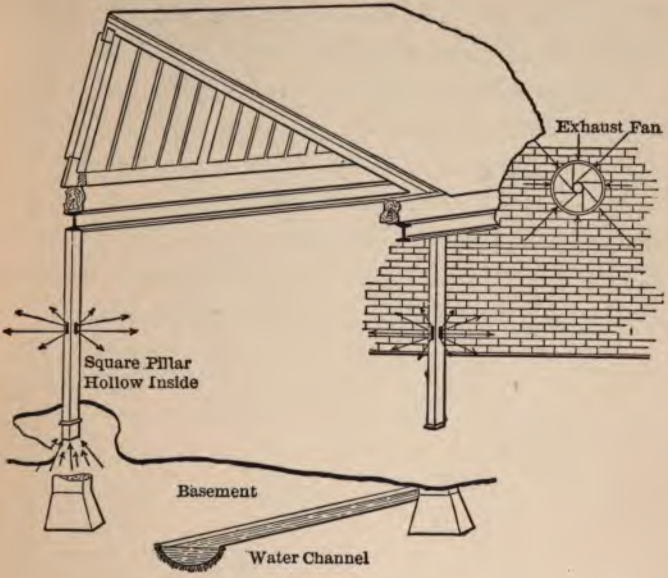

FIG. 14.

and connecting through the floor over the damp soil and water. Exhaust fans are fitted into the shed walls, creating a partial vacuum in the shed, which draws the moist air from below up through the pillars and thence into the room. In winter or when the humidity is insufficient, either exhaust steam or water from the condense pond is introduced into the basement.

This idea, though satisfactory in this particularly humid district, would not be practicable in dry climates or in sheds where a very high hygrometric degree is required, and though the exhaust system of ventilation is satisfactory for certain purposes, it cannot be compared with the "plenum" system, in my opinion, for the textile industries.

Another device which has been applied experimentally in Lancashire weave sheds is a small brush arrangement revolving in a trough of water, a separate machine or brush being fitted to each individual loom, and connected to the loom shaft. It is claimed that the fine spray created by the brush is sufficient to maintain the necessary conditions for weaving purposes.

PART V.

PART V.

In Part IV. we looked at the various methods adopted, by means of which artificial atmospheric conditions can be governed, and we are now in a position to consider the suitability of the methods described in relation to their adaptability to the American textile trades. We have seen in Part III. the average conditions prevalent in these districts, and have seen that the problem is a far more difficult one to solve in America than on the other side of the Atlantic, owing to the great range of temperatures, etc., etc.

We can summarise that a process suitable to American needs, which could in any way be called "ideal," has many functions to perform. In the first place, the process must be able to guarantee the desired degree of humidity required in all seasons of the year, winter or summer, and not only must it comprise a method of making up for natural deficiencies of moisture, but in some cases and during certain seasons it must be able to reduce excessive humidity, and act as a drying and not as a moistening plant. In summer, also, it must be able to materially cool certain rooms, a most difficult matter, and also to act as a heating and ventilating plant.

We find, therefore, that on the American continent there exists all the natural evils or enemies to the maintenance of suitable conditions for manufacture which occur in a modified form, singly or doubly, in the other textile countries of the world, and a process which would be suitable for any of these individual countries and districts would require to be supplemented to be satisfactorily applied in America.

We can therefore lay down the following individual points that must be collectively included in our "ideal" American process:

(1) To maintain a suitable degree of humidity in all seasons and in all parts of a building.

(2) To free the air from excessive humidity during certain seasons.

(3) To supply a constant and adequate supply of ventilation.

(4) To efficiently wash and free the air from all micro-organisms, effluvias, dust, soot and other foreign bodies.

(5) To efficiently cool the air of the rooms during certain seasons.

(6) To either heat the rooms in winter or to help to heat them.

(7) To combine all the above desiderata in an apparatus that will not be commercially prohibitive in first cost or cost of maintenance.

The last-named point is naturally one of the greatest interest to the prospective buyer, and as the textile trades are conducted from a practical standpoint, our problem must be looked upon practically, and a happy mean struck by which the general amelioration of existing conditions can be made to be profitable and to warrant the cost of apparatus and maintenance.

To my knowledge there are mills to-day where the conditions are excellent, through the adoption of one system for winter and another run in conjunction with it or alone for summer use. This, though it can be looked upon as a partial solution of the question, cannot be other than prohibitive in price to the average mill or corporation. The combination also of two different systems is not to be advised, especially where one machine is used as a humidifier and the other as a ventilating and cooling plant, as the effects of the one are bound to be more or less affected by the action of the other, and if a process whereby all the required conditions can be obtained is procurable, there should be no question as to which is the most suitable method to adopt.

Without entering upon an exhaustive discussion of the respective merits of the various types of humidifiers, I think the essentials already enumerated should leave no room for question as to the necessity of adopting a system including a means of ventilation or of supplementing a system by a separate means of ventilation; the choice between the two being for the purchaser to decide, being governed by his experience and the requirements of his mill. It is very generally admitted that a proven success in one locality is not always satisfactory in another, and a great deal of leeway must be allowed in dealing with our very intangible question.

If the conditions in a mill, however, are unsatisfactory, there is, in my opinion, only one method to adopt, and that is, to treat the inside of a building in such a way as to be absolutely independent of the outside atmosphere, and this is the question which I will now proceed to discuss.

To maintain certain conditions inside a building, irrespective of those pertaining to the local conditions outside, one must eliminate altogether draughts and leakages from the outside, and to do this an air pressure must be maintained inside the building above that of the atmosphere.

From this it is very evident that a fan system is required. Given this basis, therefore, we must now decide what kind of fan system is the most economical and suitable.

In solving this question we are confronted with three points of direct interest:

(1) The question of horse-power.
(2) The even distribution of the humidified air to all parts of the room.
(3) The ability to maintain a suitable pressure to eliminate the effects of the outside conditions.

The first of these three points is the one to which by far the greatest importance is given, and very little attention is paid to the other two; but if one studies the question closely from a strictly practical standpoint of interest, it is not very difficult to come to the conclusion that if by economising on power the required conditions are not obtained, the installation of the economical plant is not so much of an economy as was first imagined, and the required conditions in some mills cannot be maintained during certain seasons if attention has not been paid to the third point.

We must therefore choose a "positive" fan system to make our system worthy of the word "ideal"; at the same time we must also look on the question from a commercial standpoint, and whilst allowing an ample margin of ventilation for obtaining the required inside pressure, we must strictly define the limits of the fan system, owing to the rapid increase of power taken by fans.

Confining ourselves for the moment to the fans themselves: We find that there are two classes, *i.e.*, propeller fans and blowers.

Propeller fans are excellent means of ventilation where the question of pressure is of no importance, and if our "ideal" process were based upon exhausting the air from a room instead of forcing it in, there would be no question as to their suitability. However, experience has shown that the "plenum" system, though requiring more power to drive, is far the most efficient. We must partially if not wholly exclude the exhausting principle and limit ourselves to creating a pressure in the building to be treated, and include fans that are essentially pressure fans.

The amount of pressure to be maintained in a building is not to be determined by any hard and fast rules, and the questions of locality and environment play a most important part in the solving of this question. The only way that I have been able to successfully satisfy myself as to the requisite air change to be given by a fan system, where humidification is to be included, is to carefully determine the prevailing conditions of the district, the process of manufacture in the building, the mean and maximum temperatures and degrees of humidity inside the building, and the effects of the outside conditions upon those of the inside; and having determined by my system of reasoning the minimum air change required, to add 50% margin.

This, in view of my statement that the question has to be looked upon from a practical standpoint, may appear to be unreasonable, but my experience has shown me that in dealing with this subject the *amplest* leeway must be allowed to meet unforeseen contingencies.

I have often been asked why I calculated the capacity of a certain plant in excess of another, dealing with precisely the same class of room, in which the same process of manufacture was taking place—why I should put in a plant giving an air change of three times an hour in one case, and ten times in the other?—and I have only been able to give one answer, and that is:

"To go yourself into each of the rooms and work in them and describe why it is that whilst the work on one part of the room is running smoothly, that in the other part is causing trouble."

Practical experience in these matters is the only experience that counts, and a plant that is calculated on theory, whilst successful in one case, runs a very fair chance of being unsuccessful in another!

We have seen that those processes combining ventilation with humidification comprise three types:

(1) Ventilo-heads.

(2) The head type of humidifier and separate ventilation system.

(3) The combined systems including blower or pressure fans.

In some cases the ventilo-head system is sufficient, whilst in others it is not, but in every case the pressure systems are efficient.

From this it might be argued that if a sufficient number of ventilo-heads were installed, the installation would be as efficient as the "plenum" system, and though this is in a measure true, it would be found that the cost of such an installation would be very great and that the question so often raised in defence of the propeller fan-systems, that of power, would be found to be nearly if not quite as great as the pressure systems.

In dealing with the second point at issue—that of the equal distribution of moisture—it will be found that though the natural laws of gases aid materially in equalising the degree of humidity in all parts of a building, that if the outside influences are not sufficiently counteracted by the "plenum" in the room, those parts immediately adjacent to the sources of draughts, etc., from the outside have not the same conditions as those in the centre or parts not affected from the outside in the room.

In the head type of humidifiers, although the natural laws of gases are of great help, unless there be a sufficient number of heads, the humidity is very much localised, and is not even over the whole building. In installing such a system, therefore, ample provision for plant must be made.

The installation of two separate installations, one for humidification and the other for ventilation, though again successful in some cases, cannot be termed an "ideal" way of solving our problem, and under certain conditions there is always the danger that the currents of air created by the ventilation plant materially affect the even distribution of moisture by the humidifying system.

In combining ventilation and humidification in the same system, and seeing that the pressure exerted by the plant is sufficient to maintan an efficient "plenum" in the building, the required desiderata for success are obtained, and I consider that such a type of installation is the only one that can possibly meet the American requirements.

As I have said before, that though some conditions are successfully met with the head type, ventilo-head type, and combined head and ventilation plants, that those difficult problems to be met with in America can only be satisfactorily solved by maintaining the conditions in a building in such a way as not only to be independent of the outside conditions, but also to eliminate any interference from the outside.

So far I have partly dealt with the first and third points raised in the beginning of this part of my work, *i.e.*, the maintenance of a suitable degree of humidity, and a sufficient supply of fresh air, these two points being those which are the easiest in our study to solve, and we now come to the second point raised, that of reducing the excessive humidity in rooms during certain seasons of the year, and as this point is directly interdependent with that of cooling raised in the fifth point, I will deal with them together.

During certain seasons of the year the air is so saturated with humidity and the temperatures so high that not only have mills been put to the greatest difficulty in running their spinning departments, but in some cases they have been unable to keep their help.

These conditions are those prevailing during the "dog-days," when both the degrees of temperature and humidity are at their highest. It is unnecessary to give data as to these conditions, as all mill men are only too well aware of them. Let it suffice, therefore, to say that a relative humidity of 90% and a temperature of 90°F. are not at all uncommon.

In ring spinning rooms, the heat given off by the spindles revolving at high rate of speed is so great that whilst an empty room in 90°F. weather might be even possibly cooler than the outside temperature, it is not at all uncommon for the temperature of a ring spinning room to run up as high as 110°F. and even higher on the hottest days, and the effects of such temperatures on the help can be readily understood.

It would be almost impossible for the operatives to work in these rooms if they were deprived of ventilation, and the only ventilation that they are able to obtain in the great majority of cases is that obtained by opening the windows. By doing this during the "dog-days," however, the humidity in the room is far in excess of the required conditions for spinning, and the work is very materially affected.

It is recognised that during these periods that although by closing the windows the relative humidity could be decreased, the temperatures would become so high that the help could not work, and so the windows must be kept open.

These two questions of cooling and reduction of humidity are by far the most difficult to solve of our problem. If a mill were run as a laboratory or show room and *carte-blanche* as to first cost of plant and maintenance given, it would be quite possible to maintain the conditions at the required degrees. In a manufactory, however, the limitations are very limited, and we must therefore make our "ideal" process as "ideal" as circumstances allow. It may, however, be of interest to discuss the methods of reduction.

There is only one way to cool air and that is to take the heat out of it! There are two ways of drying the air of a room: the first is to filter it through absorbants, and the second is to first contract it by cooling, precipitating its moisture, and then to expand it again by heating. The absorption of moisture is not feasible in a case where very large rooms are dealt with, and we must therefore confine ourselves to the contraction and expansion theory.

Supposing we take a case where the outside temperature is 90°F. and the relative humidity 90%; there would then be 13.4 grains of aqueous vapour per cubic foot of air. The room to be dealt with has on this day a temperature of 100°F. and 68% of humidity (giving 13.4 grains of water per cubic foot) and it is required to reduce the temperature to 90°F. and 50% of moïsture (7.4 grains of water per cubic foot of air). We then have to introduce a sufficient volume of outside air, cooled by a certain number of degrees, not only to cool the room 10°F., but also to reduce the relative humidity of the room by 6 grains of water vapour per cubic foot of air.

The first point for consideration is the cause of the increase in the room of 10°F. over the outside temperature. This increase can be caused either by the effects of the sun's rays on the roof, or through sky-lights, or else by the heat given off by machinery. Having discovered the causes of heat and its rapidity of creation, we must proceed to make provision for introducing a sufficient volume of cool fresh air at a degree of temperature suitable to the case, and also to make provision to extract or to force out the hot vitiated air.

We can choose one of two methods to exhaust the air from the room and allowing the fresh air to enter the room over cooling surfaces, such as brine or ammonia coils, or else to put the room under a "plenum" by introducing a large volume of air as close to the floor as is reasonably possible, and to place extraction fans of a quarter the capacity of the blowers in the ceiling.

The first of these two methods would in my opinion be the most satisfactory from an economical maintenance point of view, if the "dog-day" conditions prevailed all the year round, but seeing that our process is to deal with all manner of conditions, winter, spring, summer and autumn, we must confine ourselves to the use of our combination plant.

The tendency for hot, dry air is to rise, and that of cool, damp air to fall; the introduction of the cool, fresh air at a low level and the placing of the extraction fans in the ceiling is therefore correct.

The next point to solve is the volume of air to be introduced and its temperature in proportion to the heat units created and to be extracted from the room. No hard and fast rule can be laid down here and we must leave the solution to practical experience and the conditions of the particular case. Given, however, that an air change of once every six minutes, or ten times per hour, is sufficient, we must cool this volume of introduced air to a degree where its point of saturation is not in excess of 7.4 grains of water per cubic foot, seeing that one of the desired conditions is not to have an excess of 50% of relative humidity at a temperature of 90°F. (7.4 grains of water per cubic foot). By looking up our tables we find that air at 67°F. and 100% relative humidity contains 7.3 grains of water per cubic foot, and theoretically, therefore, we must reduce the temperature of the introduced air 90°—67° = 23°F. to obtain the desired conditions.

This reduction of 23°F. when the outside air at 90°F. contains 90% of relative humidity can be obtained by passing it through either a "spray chamber" of cold water, the volume of the spray being proportionate to the temperature of the water. If well water at 50° to 55°F. can be obtained in unlimited quantities, this is by far the most economical way of getting our results. In cases where such water is not obtainable, there is only one way to get our results, and that is to cool the water by means of a refrigerating plant. Unfortunately, however, the cost of such a plant added to that of our process, would make the same prohibitive in ninety-nine cases in a hundred, and we must therefore be satisfied to live up to the adage that "half a loaf is better than none" and obtain the best results we can by taking our cooling water from the most available and coolest source, and include a pump in our system for re-circulating this water. By this means, if the plant is of sufficient capacity, the results should certainly be of very material benefit.

Without a refrigerating machine we can expect to get with such a process, applied to the ring room in question, a reduction in temperature of anywhere from 7°F. to 18°F., and that with all the windows in the room closed.

In dealing with the fourth point, in which it is desired to wash and free the air from all impurities: This is not a point of such importance in the majority of cases in America as it is in the industrial centres in Europe. In some cases, however, which I could cite where mills are situated immediately adjacent to railway lines and coal yards, should the air be taken into the mill from the side overlooking the yards, etc., a great deal of fine, impalpable coal dust and soot would be introduced into the rooms; and where fine counts are spun (necessitating the cops being on the spindles sometimes for days together) there would inevitably be loss and trouble caused by the deposit of the impurities on the foot of the cops, causing what are known as soiled or black cops. If, therefore, the air sucked in by the fans is taken from the side where the sources of these impurities exist, we must include in our process a means whereby the entering air can be efficiently freed from the same.

This can be done in a variety of ways, by wet or dry filters, spray chambers, etc., etc. In including filters, care must be taken to design them of suitably large surface, otherwise the resistance offered would be such as to reduce the volume of air dealt with by the fans to a minimum.

Dry filters are better than wet filters, as a damp surface resists the flow of air far more than when the same surface is dry. This can easily be proved by blowing or sucking air through a dry handkerchief and comparing the energy or force with that required to do the same with a wet handkerchief.

In either case the accumulation of dust and dirt on the filtering material is very rapid, and in such cases provision must be made to cleanse the same periodically, otherwise the filter would become clogged or "made up" and no air would pass through.

In the case of wet filters, thoroughly washing out the filtering material is the only method. In dry filters a vacuum arrangement, somewhat similar to the vacuum carpet cleaner, can be fitted up, with a mobile sucking mouthpiece travelling up and down and from side to side of the filter's surface. This I know to be feasible, as I have personally seen such a device; as, however, the same was shown to me in confidence, I am not at liberty to give any further description.

In cases where the outside conditions are very bad, a dry filter, although not absolutely necessary, is advisable. In cases, however, where the air is passed through a very fine spray, sprayed in a chamber of ample capacity, I am of the opinion that any need of further device is unnecessary.

Breaking up of water in the wheel of a centrifugal fan has been used for some years in Germany to free blast furnace gases from fine dust, with most excellent results, and as these dusts are far more impalpable and insoluble than the impurities generally held in suspension in the atmosphere, such a device should meet most contingencies. By adopting such a method the need of filters is done away with, and one can thus not only economise on the first cost of an installation, but also obtain the full output of the fans without reducing the same by making them suck the air through the resisting surfaces of the filters.

The sixth point is one which the individual taste must decide. Some mills are in favour of hot air heating and others are not. In the former case, it is a very simple matter to fit heater batteries in conjunction with the fans. In any case, by using hot water in winter for humidifying purposes, not only is the degree of required humidity more quickly attained and maintained, but the heating of the building is also considerably helped.

In dealing with the seventh point—that of cost on maintenance and first cost of apparatus—we come to the point which is generally uppermost in a prospective buyer's mind. The best is the cheapest is a well-known trade axiom when it is applied to the first cost of a ma-

.e, but when applied to the maintenance question it ot so enthusiastically received. It has been my en-rour to point out the facts which substantiate my ıion that efficient ventilation, and in consequence, a cient "plenum," is to the ultimate advantage of the :haser, and it certainly has been my experience that majority if not all those that have made a fair l of this method have been more than satisfied. I say no more on this question, as I have confidence time will show the truth of my statements, and "plenum" systems will be adopted in America as have been in Europe.

o summarise, therefore, those points which should olved in our "ideal" system, designed to meet the t stringent requirements which unhappily exist too uently on the American continent, we must in-e

A fan or fans, essentially of the pressure type.

A suitable system of delivery and drain piping, connected to and from the humidifying apparatus by a pump of ample capacity, sucking water from a tank to which the water from the system is drained and re-circulated.

To supply an adequate quantity of water to the tank from the coolest available source, to make up for evaporation, losses, etc., and to keep the temperature of the tank water at a reasonably low point.

(4) To include an efficient dry filter where "atomising" fans are not used, in cases where the mill is located near coal yards, etc., and to apply a suitable automatic cleansing device.

(5) To calculate the fan capacity so that the cooling of the building can be materially effected.

(6) To use warm water or atmospheric steam and water in winter, or else to include heating coils.

(7) To connect to the fans a suitable system of distributing ducts, designed to meet the pressure requirements of the fans and to eliminate all bends and other causes of resistance in the air ducts.

Although such a system as I have described will be more expensive than the systems in vogue in America, I am confident that the superior results attained will fully compensate not only for the first cost of installation, but also for the maintenance of the plant, and, it is in my opinion, only a matter of time for the advantages of the "plenum" principles to be acknowledged as the solution of the climatic problem in America.

PART VI.

PART VI.

"Conditioning" and "Hygrometry."

Introduction.

In this last part of my work I propose dealing with the conditioning or "ageing" of yarn and fabrics as shortly and as concisely as possible.

We have already seen in Parts I. and II. the standards of regain in textiles, the conditions in which cotton grows, and the general structure and peculiarities of textile fibres.

In the conditioning department of a textile factory there are two functions to perform:

(1) To fix the torsion of the yarns or fabrics.

(2) To "pack" the cops, yarns and cloth with the percentage of moisture allowed by the conditioning houses' standards.

Owing to the fusion points of the wax contained in the fibres, high temperatures have to be avoided, not only on account of the damage done, but also on account of the rapid condensation of large quantities of water on certain parts of the material, which will inevitably cause mildew and fungi in the future. Large consignments of goods have often been returned by colonial firms of merchants owing to the unsatisfactory condition of the fabrics after having been held in stock for some time, the cause of which can be traced to improper conditioning.

The Importance of Time.

To "age" under the best conditions, sufficient time must be allowed, and the more time that is given to the process the better will be the results. As, however, considerable despatch has to be used in the majority of cases, we must confine ourselves to the limits imposed by the trade conditions.

The Watering Can.

Before the conditioning house standards became a recognised power, it was not at all uncommon for the watering-can and even the hose to be freely made use of, and yarns to be sent out with a percentage of water far in excess of those allowed at the present day; this was nothing more or less than selling water at the price of the material, and such a practice cannot be too much condemned.

"Steaming."

"Steaming" was also largely practiced, but, for the reasons already mentioned, such a practice is very deleterious. The use of exhaust steam to maintain the high percentage of humidity necessary for conditioning, together with a moderate temperature, is not incorrect, if either an antiseptic, such as formaldehyde, is used;

or better still, if the cellars have an adequate and constant supply of fresh air. In either case, however, not only must the degree of temperature be limited, but care must be taken that the steam used contains no impurities.

"Conditioning" Cellars.

A very general practice has hitherto been, and even now is, to lay down a flooring of porous tiles or bricks with channels running along the middle and sides of the cellar. By keeping these tiles saturated, a great deal of moisture is evaporated by the air, and where time is no object this method cannot be bettered, if the cellar floor is periodically flushed to wash out any accumulation of impurities. As, however, time is important, the cops and fabrics are usually sent out with a lower percentage of moisture than the standards properly allow, and as this means a loss, provision in such cases should be made to make up the deficiency.

"Head-Type" Humidifiers.

Head humidifiers have been in many cases satisfactorily installed in the cellars as well as fan systems. The latter are the best, as the pressure in the cellars being higher, as a rule, than that of the atmosphere, there is a tendency for this pressure to aid the absorption of water by the yarns and fabrics.

Separate "Conditioning" Chambers.

A very excellent device that I have seen abroad is to build a brick chamber packing the skips on shelves arranged in the chamber. The flooring on which these shelves rest is made of slats, the ceiling sloping towards the sides, and lined with cork or other absorbent material, and the whole chamber hermetically sealed. The floor under the slats is concreted and slopes towards a drain outlet. Into the interspace between the concrete and the slats is delivered a large volume of air containing a high percentage of humidity. The air is delivered by a fan installed outside the chamber. A constant and very rapid circulation of air is therefore set up and passes up through the slats directly underneath and through the cop baskets, being helped by the suction from above, caused by a suction duct connected to the fan, this action being kept up continuously as long as the fan is at work.

A double chamber can be built and the fan connected to each unit by ducts with dampers arranged to cut off the chamber that is not in use. With such an arrangement the daily output of the mill can be packed into the chamber which is out of commission without subjecting the help to a highly humidified atmosphere, and also without interfering with the working of the installation, each chamber being used on alternate days.

The fan can be driven electrically and twenty-four hours is sufficient, as a rule, to properly condition the yarn.

Such a method is the best that I know of where time is a serious object; however, two days and nights are better than one to properly fix the torsion of the yarns.

The Use of Damp Sail-Cloth.

A still quicker method, but one which has its disadvantages, is to pack the cops in layers between damp sail cloths. By adopting this method a night is sufficient to give all the moisture that is required. A great deal of labour, however, is required to handle the cops, and there is also a great amount of waste caused if care is not exercised to prevent the heads of the cops from being damaged.

The Relation Between Time and Output.

The individual requirements of each mill must be taken into consideration in this department, as in the others, and no hard and fast rules can be laid down. It is, however, where possible, advisable to allow as much time as can be spared, and in all cases to make use of a suitable antiseptic, and build the cellars or arrange the baskets in such a way that there is no condensation or precipitation on the cops and material, a cause of mouldy or otherwise discoloured cops and fabrics, especially in the case of the finer grades, where Egyptian cotton, etc., is largely used.

Hygrometers.

Hygrometers, or instruments for ascertaining the degree of temperature and humidity, in all cases where they are not made use of, should at once be procured, and periodical readings taken at least three times a day and a proper record kept of the same, as a means of tracing possible discrepancies in the productions.

All up-to-date mills have thoroughly realised the importance of these instruments, and no concern that pretends to live up to this name should be without them. There are, however, still many mills where there is very little attention paid to this matter and where the wet bulb and its well of water are more often dry than wet, the excuse generally given being that the overseers and winders can tell by the "feel" when the conditions are suitable, and though this may be true, the importance of keeping records should not be overlooked, and in itself requires very little further attention or labour on the part of the man in charge.

There are many instruments on the market, all of which claim their points of excellence, but when put up against one another a difference, and very often a marked one, is generally found on comparison.

There is in my opinion only one type of instrument that can be safely depended upon, and that is a properly made and kept wet and dry bulb hygrometer, and although it is claimed that satisfactory results cannot be obtained from observations taken in stagnant air, it must be remembered that little time can be given to taking observations, and the readings obtained will be sufficiently accurate for commercial purposes. Should the mill superintendent wish to check the readings from time to time, he can very readily do so by employing a

Sling Psychrometer, but some time is required before the proper use of this instrument can be learned.

Important Points in Choosing Hygrometers.

In using hygrometers there are four points to which close attention must be paid:

(1) The muslin covering the wet bulb should be kept in good condition, as the evaporation of the water always leaves a small residuum in the meshes, which inevitably causes stiffening of the material, preventing the proper taking up of the water.

(2) The use of as pure water as possible and also to renew the muslin covering from time to time.

(3) To have the wet bulb at least 4 inches apart from the dry bulb and the well of water at least 5 inches, to prevent the dry bulb being affected by evaporation.

(4) To have the gradations cut on the stems of the thermometers themselves, and to have them properly tested before being made use of.

A very common defect in many makes of hygrometers is to have the spherical bulbs of the thermometers too long to adapt themselves quickly to the changes of temperature, and care should be taken in having the instruments tested before being put to use in the mill.

The manner in which the readings are taken is too widely known to necessitate any explanation on my part. Many ingenious devices have been brought out to obviate the use of tables and scales, and many of these can be fully relied upon, being based on standard figures, if they are used in conjunction with a correctly mounted and made wet and dry bulb hygrometer.

The use of any other kind of instrument is in my opinion to be condemned, as, to be reliable, an instrument has to be made to comply with the standard regulations enumerated above.

A proper knowledge of hygrometry is an element which plays an important part in the success of a mill manager or superintendent, and he should himself see to it that the overseers in charge of the various departments of the mill under his charge become conversant with the using of the instruments in their rooms.

In closing this work I submit, as in my preface, that the difficult conditions to be met with in America can at all events be very materially improved by adopting methods such as I have attempted to describe. I also trust that this important trade question will receive the attention it deserves, and that the many points of interest will be solved by practical demonstration in the near future.

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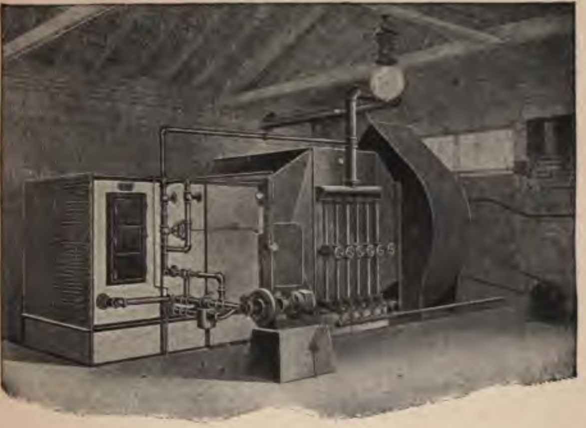

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